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Riikka Pastila (ed.)

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Radiation practices

Annual report 2018

THIS REPORT WAS PREPARED BY

Siiri-Maria Aallos-Ståhl
Elina Hallinen
Santtu Hellstén
Heli Hoilijoki
Sampsa Kaijaluoto
Venla Kuhmonen
Päivi Kurttio
Maaret Lehtinen
Reetta Nylund
Pilvi Orkasalo
Pasi Orreveteläinen
Iisa Outola
Teemu Siiskonen
Petri Sipilä
Petra Tenkanen-Rautakoski
Eija Venelampi

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Radiation practices

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Abstract

A total of 3052 safety licences for the use of ionizing radiation were current at the end of 2018. The use of radiation was controlled through regular inspections performed at places of use, test packages sent by post to dental X-ray facilities and maintenance of the Dose Register. The Radiation and Nuclear Safety Authority (STUK) conducted 592 inspections of safety-licensed practices in 2018. The inspections resulted in 393 repair orders issued. In addition, radiation safety guides were published and research was conducted in support of regulatory control.

A total of 12 002 occupationally exposed workers were subject to individual monitoring in 2018. 75 852 dose entries were recorded in the Dose Register maintained by STUK.

In 2018, regulatory control of the use of non-ionizing radiation (NIR) focused on laser equipment, sunbeds, radio appliances and cosmetic NIR applications. Forty-five cases of sales or import of dangerous laser devices were found through regulatory control. Fifteen on-site inspections of show lasers were conducted. Municipal health protection authorities submitted the details of the inspections of 30 sunbed facilities to STUK for evaluation and decision. In addition to this, five sunbed facilities were surveyed on the basis of STUK's own monitoring.

In metrological activities, national metrological standards were maintained for the calibration of radiation meters used in radiotherapy, radiation protection and X-ray imaging as well as the calibration of radon meters used for measurement of radon in air. In measurement comparisons, STUK's results were clearly within the acceptable range.

There were 110 abnormal events related to radiation use in 2018. Of these events, 30 concerned the use of radiation in industry and research, 75 the use of radiation in health care, two the use of radiation in veterinary practices and three the use of non-ionizing radiation. In addition, 1149 events and near misses with an estimated minor significance for safety were reported for health care.

In 2018, nearly 8000 radon measurements at nearly 2100 workplaces were recorded in the national radon database. At conventional workplaces, the radon concentration exceeded 400 Bq/m^3 at approximately 15 per cent of the measured workplaces. The radon concentration exceeded the new reference value of 300 Bq/m^3 at approximately 20 per cent of the measured workplaces.

Contents

Management review

The Department of Radiation Practices Regulation (STO) of the Radiation and Nuclear Safety Authority (STUK) functions as a regulatory authority on the use of ionizing and non-ionizing radiation, conducts research in support of regulatory control and maintains metrological standards for ionizing radiation.

In 2018, the general state of radiation practice safety in health care, industry and research was relatively good. One of the most significant abnormal events in the use of radiation in health care occurred to an animal attendant, who was contaminated with I-131 in connection with iodine treatment of cats. The incident was classified as an INES-2 incident, because the dose limit on the skin of the worker's neck was estimated to exceed 2 Sv.With respect to use of radiation in industry, the number of orphan radiation sources detected in metal recycling increased. Of the abnormal events reported to STUK in 2018, three involved the melting of an Am-241 sealed source in a steel manufacturing process. In eight cases, radioactive material was found in scrap metal. STUK reported three melting cases occurring within a short period of time to the IAEA. They were category 1 incidents on the INES scale.

The number of abnormal events has remained relatively stable in recent years. In 2018, there were 110 abnormal events reported to STUK, compared with 112 in 2017 and 105 in 2016. Events with minor significance for radiation safety in the health care sector can be compiled into specific categories and reported each calendar year. Altogether 1149 such events were reported in 2018, compared with 1085 events in 2017, 998 in 2016 and 755 in 2015.

In 2018, altogether 16 350 workers were subject to monitoring of radiation exposure. Of these, 12 002 were classified as radiation workers. Of the workers classified as radiation workers, approximately 7200 were engaged in radiation practices and the rest in the use of nuclear energy. The largest group of workers with also the highest occupational exposure rate is constituted by flight personnel, approximately 4300 people altogether. In 2018, there were no cases of the effective dose to a worker exceeding the annual or five-year dose limit set for workers. A collective dose of 17.37 Sv was recorded in the Dose Register in 2018 for all workers subject to monitoring of radiation exposure. Of this dose, 78 per cent was recorded for flight personnel.

In 2018, the processing of safety licence applications and other applications was occasionally congested. However, the average processing time, 14.9 days, remained within the target range. In some cases, the maximum processing time was exceeded because of a temporary resource shortage, mainly as a result of legislative work. In the health care sector, reorganizations caused by the social welfare and health care reform, such as acquisitions, are also reflected in applications for safety licences. Applications for completely new activities were also submitted for processing. In summer 2018, STUK granted a fixed-term licence for the installation and technical test operation of the first accelerator-based BNCT treatment device in the world. The device was installed at the HUH Cancer Centre in Helsinki. Clinical trials are expected to begin in the latter part of 2019.

The number of X-ray appliances in industry continued to increase. In particular, the number of X-ray appliances used for the fluoroscopy of logs has increased considerably.

Owned by VTT Technical Research Centre of Finland and located in Otaniemi, the most significant Finnish laboratory that focuses on the researching of materials and handles radioactive materials underwent transformation. A safety licence was granted to the established new Nuclear Safety House. Decommissioning of the old laboratory facilities is underway.

STUK continued to collaborate closely with the other authorities responsible for monitoring the transport of dangerous goods by means such as participation in the meetings of a group of relevant authorities.

Regulatory control of the use of non-ionizing radiation focused on providers of sunbed and beauty care services as well as laser shows.

In accordance with STUK's strategy, co-operation with universities and university hospitals was enhanced in 2018. Existing collaboration networks were reinforced, and new opportunities for research co-operation were actively surveyed. STUK has the initiative in promoting research co-operation, particularly in the fields of medical use of radiation and metrology. National architecture in radiological imaging was promoted in co-operation with the Ministry of Social Affairs and Health, KELA (the Social Insurance Institution) and the National Institute for Health and Welfare.

STUK aims to increase research collaboration with its Finnish co-operation partners in order to ensure access to up-to-date information and a high level of expertise throughout the sector. Research collaboration developed favourably. In addition, STUK participated in a number of European research projects with objectives such as receiving new recommendations from the European Commission on the use of radiation and obtaining research data necessary for Finnish users of radiation and regulatory control.

At the Radiation Safety Conference arranged by STUK in May 2018, representatives from various industries discussed the changes to be brought about by the Radiation Act reform. In addition, STUK participated in the arrangements of the Säteturvapäivät radiation safety days.

As the national metrological laboratory of ionizing radiation, STUK maintained relevant calibration and measurement methods for radiation dose quantities. The operations of STUK's national metrological laboratory were assessed and found to meet the requirements set for it. To ensure high quality, the laboratory participated in regular international measurement comparisons. The comparison measurement results for 2018 were good. Radiation meters were calibrated according to demand. Radon meter calibrations have increased tenfold in the past five years.

Good radiation and nuclear safety as well as effective regulatory control are based on up-to-date regulations. The completely revised Radiation Act and the Government Decrees subject to the Act, as well as seven new STUK Regulations entered into force on 15 December 2018. The law and decrees were revised under the leadership of the Ministry of Social Affairs and Health in close co-operation with STUK. The reform was based on the EU's radiation protection directive. National requirements were revised at the same time. The reform was carried out in order to be able to ensure the future safety of the continuously evolving and expanding use of radiation as well as modernize and improve regulatory activities and apply a more risk-based approach.

1 General

"Use of radiation" refers to the use and manufacture of and trade in radiation equipment and radioactive materials, and to associated activities, such as possessing, safekeeping, servicing, repairing, installing, importing, exporting, storing and transporting them, and the process of rendering radioactive waste harmless. "Radiation practice" refers to use of radiation and to any activity or circumstances in which human exposure to natural radiation (such as radon) is or may be hazardous to health.

"Radiation" refers to both ionizing and non-ionizing radiation.

The Department of Radiation Practices Regulation (STO) at STUK is responsible for the regulatory control of the use of radiation and other practices causing exposure to radiation in Finland, while the Department of Environmental Radiation Surveillance (VALO) at STUK is responsible for the regulatory control of exposure to natural radiation excluding cosmic radiation.

1.1 Principal key figures

The principal key figures for the use of radiation and other practices causing exposure to radiation are shown in Figures 1–4.

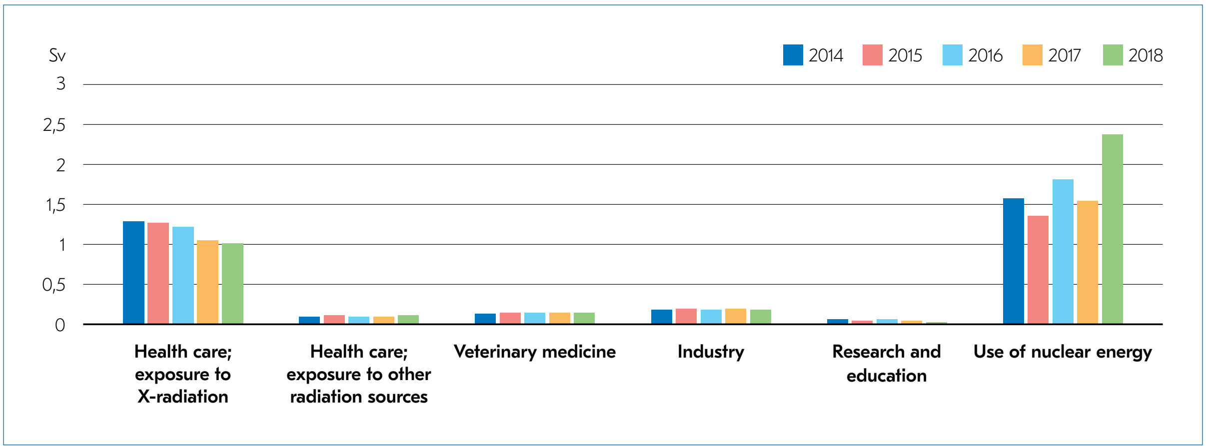

FIGURE 1. Combined doses ($H_p(10)$) of workers subject to individual monitoring by occupational category, 2014–2018. $H_p(10)$ values are generally (sufficiently accurate) approximations of the effective dose. An exception to this is the use of X-rays in health care and veterinary practices, in which workers use personal protective shields and the dose is measured by a dosemeter on the exposed side of the shield. The effective dose is then obtained by dividing the $H_p(10)$ value by a factor between 10 and 60. In addition to the occupational categories specified in the graph, a few people subject to individual monitoring work in the following fields: manufacturing of radioactive materials, installation/servicing/technical test operation, trade/import/export and services pertaining to the use of radiation and radioactive materials (see Tables 9 and 10 in Appendix 1).

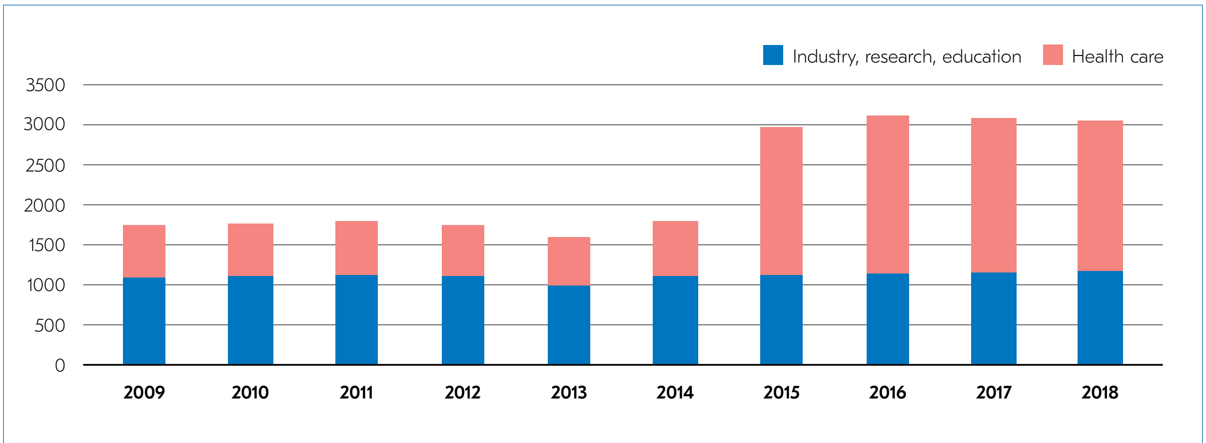

FIGURE 2. Current safety licences, 2009–2018. The increase in health care licences is due to the dental X-ray practices being changed from registered activities to activities that are subject to a licence.

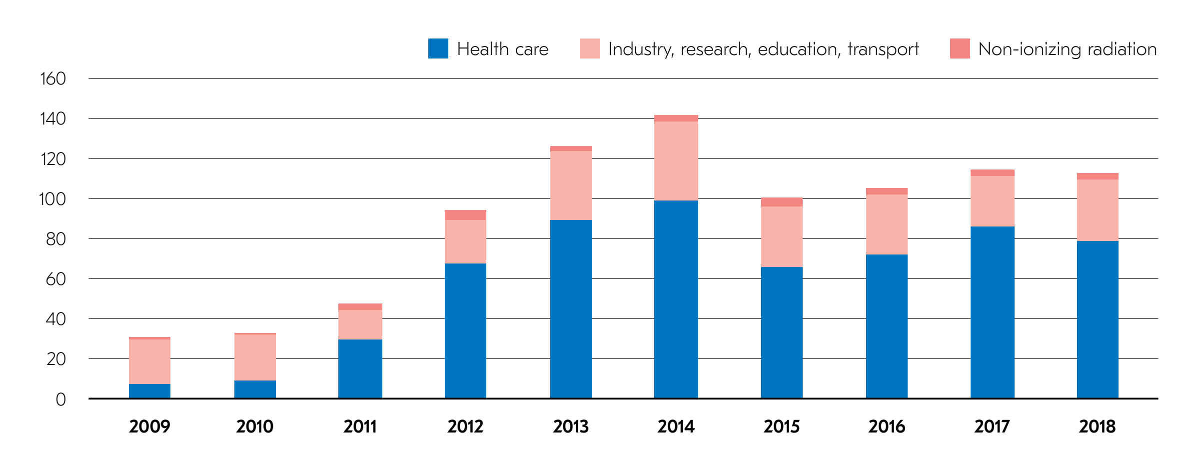

FIGURE 3. Abnormal events, 2009–2018.

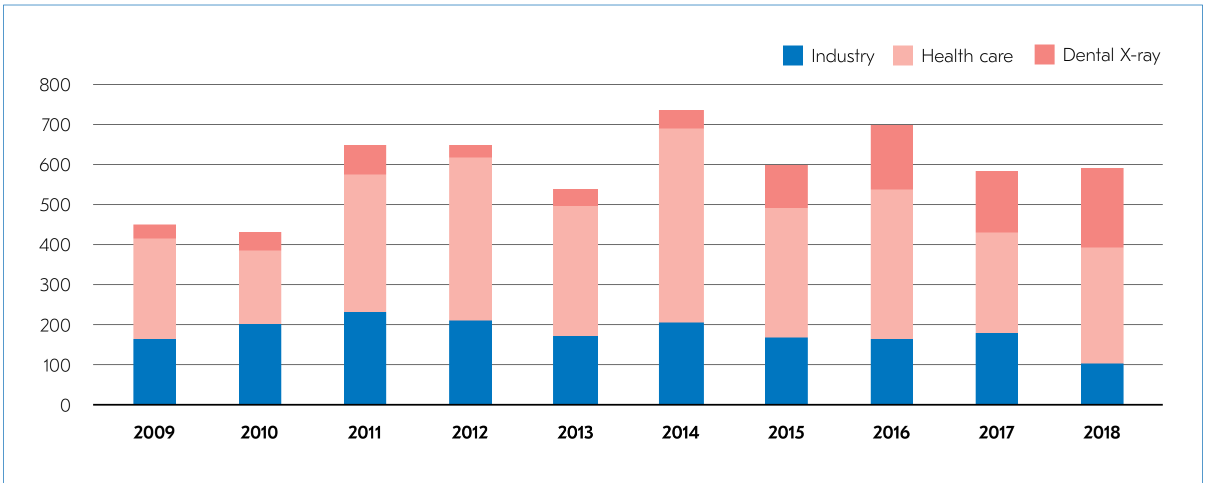

FIGURE 4. Inspections, 2009–2018.

2 Regulatory control of the use of ionizing radiation

2.1 Use of radiation in health care, dental care and veterinary practices

Safety licences

At the end of 2018, there were 1608 current safety licences for the use of radiation in health care (see also Figure 2) and 277 licences concerning veterinary practices. A total of 990 licensing decisions (new licences, amendments to existing licenses and terminations of licences) were issued during the year. The average time for processing a health care safety licence application was 12.2 days. Table 1 of Appendix 1 shows the numerical distribution of the radiation practices referred to in these licences.

Radiation appliances, sources and laboratories

Table 2 in Appendix 1 shows details of radiation sources and appliances, and of radionuclide laboratories used in health care and veterinary practices at the end of 2018.

X-ray practices, dental X-ray practices and veterinary practices

In 2017, STUK set new diagnostic reference levels for patients' radiation exposure in conventional X-ray examinations of children, including chest X-ray examinations as well as panoramic tomography of the teeth and jaws. The results of an investigation coordinated by STUK specifying European reference levels for the use of cardiologic radiation were published in 2018.

At the Radiation Safety Conference arranged by STUK, representatives from different industries discussed the changes to be brought about by the Radiation Act reform. In addition, STUK participated in the arrangements of the Säteturvapäivät radiation safety days.

During inspections of X-ray practices in health care, STUK detected 18 examinations in which the dose exceeded the reference level. Some of these were different examinations performed using the same device. As a result of these, STUK issued repair orders for the inspected sites, requesting the responsible party to investigate whether an adequate image quality could be achieved with a lower dose. The responsible parties were also required to make the necessary amendments to their imaging practices. In some cases, it was found that a lower dose level would result in an unacceptable image quality. In addition to these, in connection with regulatory control, STUK noticed doses exceeding the reference level on 12 dental panoramic tomography appliances and 13 intraoral X-ray appliances. No radiation doses were detected in regulatory control that endangered the safety of an individual patient. Nine devices without a safety licence were detected in inspections. The responsible parties were told to immediately either apply for a licence or stop using the appliance.

The guide on the safe use of radiation in cardiology (''Säteilyn käytön turvallisuus kardiologiassa'') was published in 2018, prepared by STUK in collaboration with the Finnish Cardiac Society and experts specializing in the use of radiation in cardiology.

STUK has participated in the ''Licensing and supervision'' key project to develop the range of services provided by social and health care service companies, coordinated by the Ministry of Employment and the Economy and led by Valvira. In addition, STUK participated in the 'Smart services and robotization' digitalization project that is led by the Ministry of Social Affairs and Health and falls within its administrative branch. STUK also participated in the Kvarkki project for the implementation of national architecture in radiological imaging (the project for imaging material archiving run by the National Institute for Health and Welfare and KELA) by issuing statements and providing consulting with project plans.

STUK participated in the Scientific Committee of the EUCLID project coordinated by the European Society of Radiology. The project aims to establish indication-based European reference levels for the most common CT scans, conventional X-ray examinations and interventional radiology.

STUK participated in the work of the Nordic Group for Medical Applications (NGMA) relating to the use of radiation in health care. The annual meeting of the group in August 2018 discussed, among other things, the Nordic joint inspection of an appliance manufacturer and the ongoing Nordic reference level project. In addition, STUK participated in the activities of HERCA (Heads of the European Radiological Protection Competent Authorities).

X-ray equipment suppliers reported the X-ray appliances installed or reinstalled in health care practices in 2018 to STUK. The survey conducted found 12 X-ray appliances for which a safety licence had not been applied before they were taken into use. In addition, 13 dental X-ray appliances not reported to STUK were found in the survey. In connection with the inspections, STUK became aware of nine health care X-ray appliances without a safety licence. Safety licence applications were submitted for these appliances.

In 2018, STUK received 42 reports on abnormal events related to X-ray practices in health care (section 2.8). Incidents with minor significance for safety can be reported in annual summaries. A total of 1149 such events were reported.

Nuclear medicine

Similar to the previous year, the inspections concerning nuclear medicine paid particular attention to the performing of contamination measurements at regular intervals and always after finishing work. Hand and foot contamination control devices have been recommended for measuring the contamination of workers. After several years of recommending, nuclear medicine units have started acquiring these devices. Contamination measurements are carried out and their results documented more frequently than before. Despite this, contamination has often been detected in inspections, as well as radioactive rubbish in places where such rubbish should not be kept.

Transports of radioactive materials to and from nuclear medicine units have been inspected in collaboration with the police. Transport inspections have mainly been carried out in connection with normal inspections of locations in which radiation is used, without notifying the transport company in advance. Shortcomings in transport arrangements have been detected in these inspections, and the police have imposed a fine on the driver in these cases. No significant defects have been detected in transport-related procedures at hospitals.

The increase in PET/CT scans is reflected in the purchasing of equipment and the initiation of scanning practices at new locations of use.

Radiotherapy

Radiotherapy was provided at all five university hospitals, seven central hospitals and one private clinic to approximately 16 000 patients. In 2018, STUK conducted five commissioning inspections of radiotherapy equipment, one commissioning inspection of a CT simulator and 38 periodic inspections.

The comparative measurements between STUK and hospitals revealed that the treatment dose accuracy at hospitals was very good: the average difference was 0.2% in photon beams (standard deviation 0.3%), 0.4% in electron beams (standard deviation 0.5%) and 0.1% in afterloading sources (standard deviation 1.5%). The comparative measurements did not reveal any dose deviations that would compromise the safety of treatment.

When controlling the accuracy of the patient dose in radiotherapy, the multi-field plans calculated using the dose calculation system were compared with the corresponding measurement results. Inspections of dose calculation systems that affect patient doses were conducted on more than 500 radiotherapy beams. The calculation accuracy of the dose planning programmes of hospitals and the accuracy of the input data can be considered as very good. No deviations of over three per cent were detected.

In 2018, a permission was granted for the installation and test operation of a boron neutron capture device. The device will be used for the administration of treatments similar to those administered using the FIR-1 reactor in Otaniemi, Espoo. However, a nuclear reactor will not be needed to produce radiation; neutrons are produced in a particle accelerator.

2.2 Use of radiation in industry, research and education

Safety licences

At the end of 2018, there were 1167 current safety licences for the use of radiation in industry, research and education (see also Figure 2). A total of 589 licensing decisions (new licences, amendments to existing licenses and terminations of licences) were issued during the year.

The average time for processing a safety licence application was 19.1 days. Table 3 of Appendix 1 shows the numerical distribution of the radiation practices referred to in these licences.

Radiation appliances, sources and laboratories

Figure 5 shows the number of appliances containing radioactive materials used in industry, research and education in the last ten years. The number has remained nearly unchanged for a long time.

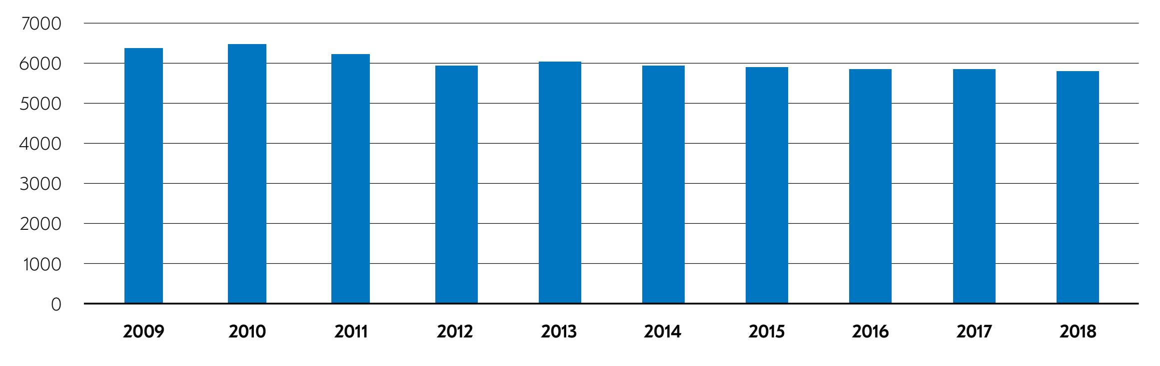

FIGURE 5. Appliances containing radioactive materials, 2009–2018.

Figure 6 shows the number of X-ray appliances in the last ten years. The number has almost doubled in ten years. Appliances containing radioactive substance have, to some extent, been replaced by X-ray appliances, in addition to which new scanning and analysis device applications have been introduced.

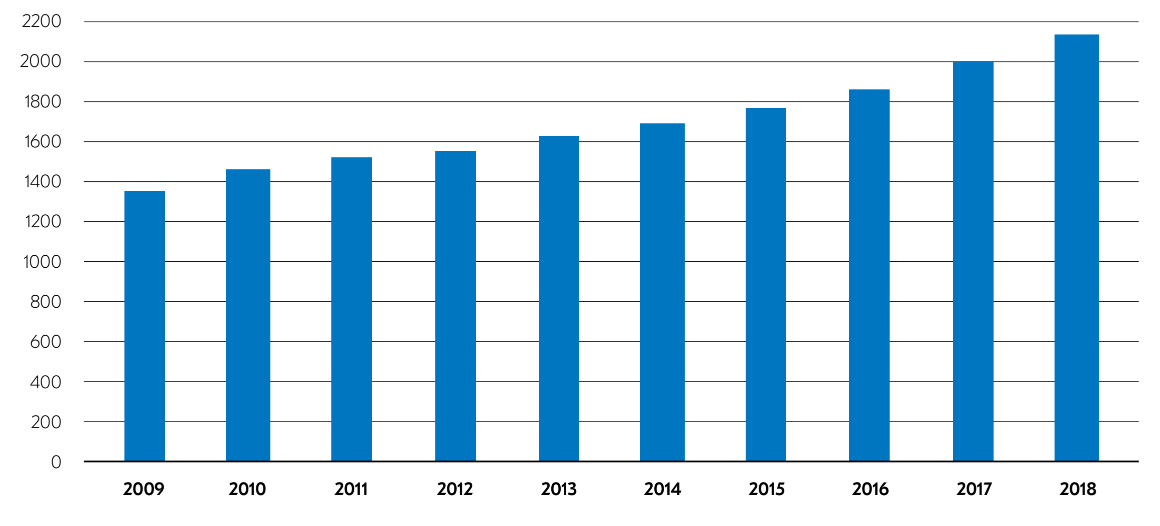

FIGURE 6. X-ray appliances, 2009–2018.

Table 4 in Appendix 1 shows details of the numbers of radiation sources and appliances as well as radionuclide laboratories in industry, research and education at the end of 2018.

Table 5 in Appendix 1 shows details of radionuclides used in sealed sources.

Use of radiation in industry, research and education

The use of radiation in industry, research and education also includes its use in services, installation and maintenance work, the sale and manufacture of radioactive materials, and the transport of radioactive materials.

STUK inspects licence holders' transportable radiation sources, as well as their use and transport arrangements in accordance with its plan. In connection with the inspections, repair orders were issued on any detected shortcomings in transport arrangements, and compliance with the orders was controlled.

Two applications concerning transport of radioactive materials were submitted to STUK for processing in 2018. Both were related to the transport of old sealed sources.

STUK continued its co-operation with the other regulatory authorities responsible for monitoring the transport of dangerous goods by participating in the meetings of a group coordinated by Finnish Transport Safety Agency (Trafi) and by participating in a joint inspection.

STUK finalized a guide on security arrangements to help responsible parties to meet the requirements.

Towards the end of 2018, STUK sent a questionnaire to radiography companies to survey compliance with the obligations pursuant to the new Radiation Act concerning external workers. The results of the survey will be used in the planning of supervision. With respect to the methods of using radiation, a particular increase was seen in the number of appliances used for the fluoroscopy of logs. Many commissioning inspections were also related to these appliances.

2.3 Inspections of licensed radiation practices

Health care, dental care and veterinary practices

In 2018, a total of 490 inspections were conducted on the use of radiation in health care and veterinary practices. Of these, 45 were inspections on veterinary practices. These inspections resulted in 238 repair orders issued to the responsible parties. Nine appliances were found that did not have the safety licence required for their use. Eighteen doses exceeding the reference level were measured.

Approximately 1300 responsible parties were engaged in dental X-ray practices in 2018. Patient radiation exposure from dental X-ray imaging was measured in 924 intraoral X-ray appliances using testing equipment sent by post (altogether 1000 test packages were sent). The average dose was 1.1 mGy. The dose refers to the dose on the surface of the cheek (Entrance

Surface Dose, ESD) when imaging a tooth. The reference level of 2.5 mGy was exceeded in 13 appliances.

In 2018, STUK inspected 198 panoramic tomography X-ray appliances used in conventional dental X-ray practices. The inspections focused on the operations of major responsible parties instead of appliance inspections. Most of the deficiencies observed in these inspections were related to quality control, an appliance and its auxiliary instruments or accessories, or the accuracy of the registration information. Doses exceeding reference levels were detected in 12 panoramic tomography X-ray appliances.

After the inspections, a feedback survey was sent to the respective radiation safety officers, asking them to provide their opinion on the inspections. Most of the respondents found that the inspections were useful and the repair orders issued were justified. Respondents were satisfied with the content of the inspection protocols and mainly also the speed of their preparation.

Industry, research and education

Inspections in 2018

In 2018, a total of 102 inspections were conducted at locations where radiation is used in industry, research or education. Periodic inspections are performed every 2–8 years in accordance with the annual plan, depending on the category and extent of operations. In addition to this, the objective is to inspect radiation practices pertaining to new safety licences before operations are commenced or within a year of issuing the licence. In 2018, this objective was not achieved. Some of the licences were not inspected for timetable-related reasons or because the licence holder was not active in 2018. The date of inspection is normally agreed on in advance with the radiation safety officer. Of the inspections, 86 were periodic and 16 commissioning inspections.

After the inspections, a feedback questionnaire was sent to the respective radiation safety officers, asking for their opinion on the inspections. Most of the respondents found that the inspections were useful and the repair orders issued were justified. Respondents were particularly satisfied with the post-inspection review that focused on the findings and the orders issued on the basis of them. In some cases, radiation safety officers reported that the inspection protocol took too long to arrive after the inspection. In general, respondents found that the inspections improve radiation safety. Feedback on the inspections and the professional expertise of the inspectors was positive.

Unannounced inspections

No unannounced inspections were carried out in 2018.

2.4 Manufacture, import and export of radioactive materials

Details of deliveries of radioactive materials to and from Finland and the manufacture of such materials in Finland in 2018 are shown in Tables 6 and 7 of Appendix 1. The figures in the tables are based on data gathered from holders of safety licences who are engaged in trade, import, export or manufacture.

The tables do not include the following information:

- Radioactive materials procured by responsible parties for their own use from other countries within the European Union, and consigned from said use to other European Union countries.
- Radioactive materials delivered to other countries via Finland.
- Sealed sources with equal or lower activity than the exemption value.
- Smoke detectors and fire alarm system ion detectors containing americium (Am-241). Approximately 50 500 of these devices were imported with a combined activity of about 1.7 GBq.
- Lamps and fuses containing radioactive substances imported to Finland. Some special lamps and fuses contain small quantities of tritium (H-3), krypton (Kr-85) or thorium (Th-232).
- Unsealed radioactive sources imported to Finland and exported from Finland. On the basis of activity, the most common unsealed sources imported were Mo-99, Lu-177, I-131, I-123, Br-82, W-188, P-32, Y-90, Fe-55 and F-18.

At the beginning of 2019, STUK requested reports from all vendors of industry and research X-ray equipment operating in Finland (37 vendors) on appliances delivered in 2018 and their holders. According to the delivery information, it was initially found that three responsible parties did not have a licence for the operation or possession of X-ray appliances. In addition, it was found that 10 licence holders had not reported their new X-ray appliances to STUK. STUK controlled that the shortcomings detected were rectified and safety licence applications for the use of all the aforementioned appliances were submitted or that the appliances were appropriately incorporated into an existing safety licence.

2.5 Radiation doses to workers

A total of 12 002 occupationally exposed workers were subject to individual monitoring in 2018. Including doses below the recording level, a total of 75 852 dose records were entered in the Dose Register maintained by STUK. This figure includes the dose records of workers exposed to natural radiation – radon and cosmic radiation.

In 2018, there were no cases of the effective dose to a worker exceeding the annual dose limit of 50 mSv or the five-year dose limit of 100 mSv set for workers. The shallow dose Hp(0.07) to one worker considerably exceeded the annual limit (500 mSv) for equivalent dose to the skin. As a result of a radiation safety incident, the skin on the neck of an animal attendant was exposed to the radioactive iodine isotope 131, causing a shallow dose Hp(0.07)of 21 000 mSv.

The average occupational doses were of the same magnitude as in previous years. The combined doses ($H_p(10)$) to workers were approximately 1.46 Sv in the use of radiation and approximately 2.37 Sv in the use of nuclear energy. The total dose in the use of radiation decreased by 3.4 per cent compared with the previous year. In the use of nuclear energy, the total dose was 55.7 per cent higher than the previous year. The total dose in the use of nuclear energy varies considerably from year to year, depending on the duration of annual nuclear power plant servicing and the type of the servicing tasks at these facilities. The highest individual dose resulting from radiation work at Finnish nuclear power plants was 14.8 mSv.

In the health care sector, the highest $H_p(10)$ dose (40.3 mSv) was recorded for an interventional radiologist. The highest $H_p(10)$ dose in veterinary practice (6.5 mSv) was recorded for a veterinarian. These correspond to effective doses of approximately 1.3 and 0.2 mSv, respectively. The highest $H_p(10)$ dose in health care from a source other than X-radiation (4.7 mSv) was recorded for a radiographer who used several radiation sources. In industry, the highest $H_p(10)$ dose (6.8 mSv) was recorded for an individual performing tracer tests. In research, the individual exposed to the highest $H_p(10)$ dose, 2.9 mSv, used several different types of sources. In the production and conditioning of radioisotopes, the highest $H_p(10)$ dose was 10.6 mSv.

In some tasks, such as the handling of unsealed sources, workers are exposed to radiation unevenly. In such cases, the dose to the hands, for example, may be considerably high, even when the effective dose is relatively low. A specific annual dose limit, 500 mSv has been specified for skin, and workers use a so-called finger dosemeter to monitor radiation doses to the hands. In 2018, the dose to the hands did not exceed the annual dose limit for any worker. The highest annual dose was 148.0 mSv, measured for a researcher. In health care, industry and research, the highest doses to the skin of the hands have increased to some extent from the previous year, while the doses have slightly decreased in the production of radioisotopes. With the exception of the production of radioisotopes, the number of workers using finger dosemeterdosemeters has also increased slightly compared with the previous year. Of all workers handling unsealed sources, only three received a dose of over 100 mSv to the skin of the hands.

Radon at workplaces

Dose information of workers exposed to natural radiation at work is also recorded in the Dose Register.

In 2018, nine workplaces were under an obligation to organize radon exposure monitoring of their workers and any subcontractors' workers. This concerned 14 employers. Workers from several companies may work at the same workplace. Altogether 95 workers were subject to radon exposure monitoring during the year, and their doses were recorded in the Dose Register. At six sites, successful radon mitigation measures were carried out. By the end of the year, workers of only three responsible parties were still subject to radon exposure monitoring.

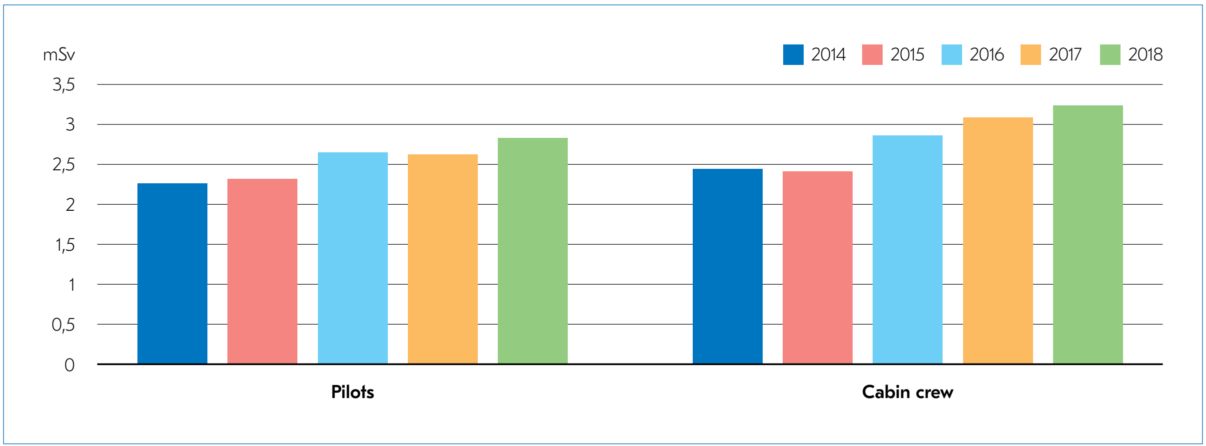

FIGURE 7. Average doses to aircrews, 2014–2018.

Cosmic radiation

The doses to the workers of three airlines were entered in STUK's dose register in 2018. The 6 mSv limiting value for the effective dose, stipulated in Guide ST 12.4, was not exceeded for any worker. The highest individual annual doses recorded were 5.4 mSv for cockpit personnel and 5.7 mSv for cabin crew. The average annual doses were 2.8 mSv for cockpit personnel and 3.2 mSv for cabin crew. The average doses from 2014 to 2018 are presented in Figure 7.

Compared with the previous year, the number of flight crew workers increased by 9.9 per cent and the collective dose to workers increased by 16.6 per cent. Table 8 of Appendix 1 shows the number of workers subject to individual monitoring of radiation exposure and the total doses to them.

Table 9 of Appendix 1 shows the number of radiation workers subject to individual monitoring over the last five years by field of activity. The combined doses to workers by field of activity are shown in Figure 1 (item 1.1) and in Table 10 in Appendix 1. Table 11 in Appendix 1 shows the doses in 2018 to workers subject to high levels of exposure and to large worker groups.

2.6 Approval decisions and verification of competence

Training organizations providing radiation protection training for radiation safety officers

In Guide ST 1.8, STUK stipulates the minimum qualifications of the radiation safety officers who are responsible for the safe use of radiation. Training organizations that arrange training and competence exams for radiation safety officers must apply to STUK for approval to arrange such exams.

In 2018, approval decisions to arrange exams and training for radiation safety officers were issued to five training organizations. A total of 20 training organizations held valid approval decisions at the end of 2018. The approved training organizations are listed on STUK's website (www.stuk.fi).

Parties engaged in aviation operations

In 2018, STUK did not inspect any airlines. The next inspections are due in 2019.

Approval decisions for dosimetric services and measurement methods

In 2018, STUK did not approve any new dosimetric services or measurement methods.

Approval decisions for radon measuring equipment

Five new approval decisions for a radon measurement method were issued in 2018. A list of organizations with measuring methods that have been approved in accordance with the requirements of Guide ST 1.9 is found on the STUK website. It includes the organizations that have consented to their names being published. Radon measuring equipment must also be appropriately calibrated.

2.7 Radioactive waste

STUK maintains a national storage facility for low-level radioactive waste. The amounts of the most significant types of waste kept in the storage facility at the end of 2018 are shown in Table 12 of Appendix 1. Since the beginning of 2017, some of the waste has been disposed at the TVO's final disposal repository for nuclear power plant waste.

2.8 Abnormal events

Pursuant to section 17 of the Radiation Decree (1512/1991), any abnormal event pertaining to the use of radiation that is substantially detrimental to safety at the place where the radiation is used or in its environs must be reported to STUK without delay. Similarly, any disappearance, theft or other loss of a radiation source such that it ceases to be in the possession of the holder of the safety licence must be reported. Any other abnormal observation or information of essential significance for the radiation safety of workers, other people or the environment must also be reported.

A total of 110 abnormal events of the use of ionizing radiation were reported to STUK in 2018. Some of the abnormal events that occurred in 2018 were not reported to STUK until early 2019.

Of these reports, 75 concerned the use of radiation in health care and 30 the use of radiation in industry. Two abnormal events were reported in veterinary practices. The numbers of abnormal events that occurred in Finland in 2009–2018 are shown in Figure 3 (item 1.1), including abnormal events in the use of non-ionizing radiation, which are described in more detail in item 4.7.

Abnormal events in X-ray practices in health care that are of minor significance for safety and do not require immediate reporting may be compiled and reported together annually. An annual notification differs from immediate reports in that annual notifications only list the number of abnormal events under each respective event category. Altogether 1149 notifications concerning the year 2018 were received from 62 parties, reporting a total of 971 abnormal events and 178 near misses. The numbers of abnormal events reported in annual notifications are shown by category in Table 1 below.

TABLE 1. Abnormal events in health care reported through annual notification.

Exposed party	Type of abnormal event	Cause or contributing factor	Number of events per year
Abnormal events related to the referral			
Wrong patient	Referral written for a wrong person	Human error	**31**
		Human error, the high likelihood of errors in the referral system*) a contributing factor	**8**
Patient	Incorrect examination or anatomical object in the referral	Human error	**54**
		Human error, the high likelihood of errors in the referral system*) a contributing factor	**5**
	Other error in referral		**59**
Abnormal events related to the performance of the examination			
Wrong patient	Wrong patient examined	The patient's identity was not verified before the examination	**17**
Patient	An incorrect examination was performed or an incorrect anatomical object was imaged	Human error during the performance of the examination	**73**
	Failed examination or an excess exposure related to the examination	Incorrect or inadequate instructions	**14**
		Human error during the performance of the examination	**214**
Extraordinary exposure, other events			
Patient	Failed examination or an excess exposure related to the examination	Isolated case of equipment failure	**187**
		The high likelihood of errors in equipment, an auxiliary appliance or system*) as a contributing factor	**264**
	Examination repeated unnecessarily	No information available on earlier similar examination, or results from earlier examination not available	**20**
Patient and worker	Worker also exposed because of the abnormal event mentioned above (when the worker's exposure is not significant)		**5**
Worker	Worker exposure (when the exposure is not significant)		**10**
Other event:			**17**
Unintended exposure of the foetus			
Foetus	Pregnant person examined	Pregnancy at such an early stage that it cannot be verified	**0**
		The possibility of a pregnancy was not considered before the procedure	**1**
A near miss that caused actions to be taken at the place of radiation use			
	When a more detailed report to the authorities is not considered relevant		**178**

*) A high likelihood of errors refers to the poor usability of equipment or a system, allowing extraordinary radiation exposure to be caused by an easily occurring human error.

In addition to the 16 categories specified in advance (see Guide ST 3.3), the events reported in annual notifications (1149 in total) were divided into other events with minor significance in terms of radiation safety and into undefined near misses. Additional information was reported for some events. Nearly half of the reported events concerned various equipment or system failures. Imaging of wrong patient was reported 56 times, and a foetus was inadvertently exposed to radiation in one case. This was the fourth year when annual notifications were collected, and the number of notifications did not significantly change from last year.

The abnormal events in the use of radiation in health care are presented below, grouped by the type of radiation use. More details are provided on typical or significant events.

Abnormal events in health care

Abnormal events in X-ray practices

In health care X-ray practices, 42 abnormal events were reported immediately following the event, compared with 48 events in 2017. The most common reasons for an abnormal event in 2018 were various equipment failures (19 cases) and a human error during an examination (12 cases). The highest individual exposure, 42 mSv, was caused to a patient by two failed CT scans. In the case in question, a CT examination of the aorta was immediately interrupted after starting the scan. It was decided to restart the examination without a new contrast medium injection, but the timing of the contrast medium was not in alignment with the examination. The failed examination was finally repeated using another appliance.

Example event 1:
A patient was given a referral to a CT scan of the carotid and cerebral arteries. On the same occasion, an appointment for the scan two days later was booked for the patient. However, the patient became worse and the requested examination was performed as an urgent procedure on the following day on a different referral. The original referral was accidentally not deleted, which is why the patient was needlessly scanned again on the following day in accordance with the original referral. The patient was exposed to an extra effective dose of approximately 3.3 mSv.

Example event 2:
A radiologist, two radiographers and an intern were exposed to the radiation emitted from a patient who had had a radionuclide scan. The patient had received 600 Mbq of Technetium-99m in connection with a scintigraphy of the bones. Approximately two hours later on the same day, a nephrostomy was made under angiography without knowledge of the radionuclide scan. The patient had been fetched from the ward to the X-ray unit and they did not know that the patient had received isotopic substance. The ward had received after care instructions on how to act when a patient has received isotopic substance, but the patient transporters had not been informed about the matter. Therefore, the people performing

the nephrostomy did not know that the patient was radioactive. The X-ray unit was not informed about this until the following day. Taking into account the lead vest worn by the radiologist, it was estimated that the radiologist received an extra effective dose of under 80 μSv, while the radiographers participating in the procedure received under 30 μSv and the intern received approximately 10 μSv.

Example event 3:
In connection with the update of the control computer of the CBCT appliance, the software version of the appliance was updated. Because of this, in certain situations, the coronal sections were not stored in the normal radiological orientation, i.e. the left side of the patient is shown on the right. In addition, because of the modality of coronal images, clinicians cannot see the side markers of the stored images. This event was caused by an error in the functioning of the software. When this was noticed, it was found out that among the approximately 140 patients scanned after the update, there were 12 cases in which the images had not been stored in the correct radiological orientation. These cases may have resulted in a hazardous situation because of a possibly incorrect diagnosis.

The coronal images with an incorrect orientation were deleted from PACS and the doctors treating these patients were informed. Coronal sections with the correct orientation could be generated when necessary. After this, coronal sections were not made until the software error was corrected.

Abnormal events in nuclear medicine units

Nuclear medicine units in the health care sector reported 31 abnormal events. The number was nearly the same as in 2017 (34 abnormal events reported). There is annual variation in the number of reports on abnormal events, shown in figure 3.

Five of the reports on abnormal events concerned cases in which the patient's condition or unwillingness to co-operate had prevented performing the examination. Five reports were related to examination failures due to employees' human error. In four cases, the injection of a radiopharmaceutical had failed. A patient was exposed in 23 cases and an employee in six cases.

The highest individual extra exposure of a patient caused by an abnormal event was 12 mSv. The extra exposure was caused when the patient said after the CT scan that it was not possible to remain in the same position for the PET scan. The CT scan was repeated after repositioning the patient to enable being in the same position during the PET and CT scans.

The levels of radiation exposure of personnel caused by abnormal events in nuclear medicine were low in 2018. The highest effective doses amounted to a few tens of micro sieverts.

Example event 1:
A laboratory assistant had added 11 GBq of ^{99m}Tc in a sestamibi bottle but did not remember whether he/she had pulled out the protective gas at the same time. After five minutes of boiling, the bottle exploded in the dry boiler. At the time of explosion, the laboratory assistant and a specializing physicist were present in the hot laboratory. The laboratory

assistant and specializing physicist were wearing appropriate protective equipment, including a breathing mask, protective cap, lead apron or loose sleeves. They had their backs towards the bottle at the moment of explosion. Despite the protective equipment, contamination was detected on both of their faces. After the explosion, they both took their clothes off and took a shower. The contaminated skin areas were found by contamination measurements, and the necessary cleaning procedures were carried out. It was estimated that the event exposed the skin of the laboratory assistant and specializing physicist to effective doses of approximately 3 µSv and 7 µSv, respectively, and to equivalent doses of 70 µSv and 820 µSv, respectively. The medical physicist attending to the incident was exposed to an effective dose of approximately 12 µSv.

Example event 2:
The CT unit of an imaging department PET-CT appliance stopped working. Therefore four patients who had received ^{18}F-FDG radiopharmaceutical were not scanned. The unnecessary exposure to the patients resulting from the event were 3.3 mSv, 4.9 mSv, 5.3 mSv and 4.4 mSv, respectively.

Example event 3:
A patient receiving ^{177}Lu-ocreotide therapy was administered a radiopharmaceutical infusion in the hospital ward. The patient was administered approximately 7,000 MBq of the ^{177}Lu radiopharmaceutical intravenously in a volume of 500 ml. When the infusion equipment was being returned to the nuclear medicine department, the infusion tube fell from the holder to the lift floor. Approximately 1.5 MBq of radioactivity spread on the lift floor and the nurse's shoes. The lift and the nurse's shoe were measured with a contamination meter and cleaned. Contamination was not detected in other areas, and it did not spread on the skin of the personnel or patients. The lift was kept out of use, until the surface activity of the floor had fallen below 4 Bq/cm2. Those attending to the incident were exposed to less than 1 µSv, and no internal contamination was detected.

Abnormal events in radiotherapy

Two abnormal events were reported in radiotherapy. In the first case, an employee from the radiotherapy unit was in the brachytherapy treatment room checking a treatment appliance, when the CT scanner was started. The door to the bunker had been closed without the person noticing it, and after a moment the warming-up sequence of the CT scanner in the room was started. Before closing the door, the persons in the control room had loudly shouted into the treatment room, asking if anyone was there. As they did not receive any answer, they closed the door. The person in the treatment room did not hear the shouting and did not see the doors closing. When realizing that the CT appliance was about to start running, the person in the room pressed the emergency button, which immediately switched the CT appliance off. Radiation exposure caused to the person in the treatment room was very low. In another case, the patient had been referred to a CBCT scan to ensure the location of the site to be treated. The CBCT scan was performed as normal. When transferring the table back to the isocentre, the OBI software was jammed. Therefore, the table could not be moved and it was not possible to use the CBCT image. Because of the crashing of the software, the CBCT scan had to be repeated and the patient received an extra radiation dose. The retake was successful and treatment was carried out according to plan.

Abnormal events in veterinary practices

Two abnormal events were reported in veterinary practices. In the first case, the neck of an animal attendant was contaminated by ^{131}I in connection with iodine therapy administered to cats. The contamination was probably caused by the ^{131}I fluid left in the fur of a cat on a Wednesday. The animal attendant did not notice the contamination of the neck until Friday. After reporting the contamination, the animal attendant was instructed by the radiation safety officer to take an iodine tablet. On Saturday, the radiation safety officer performed more detailed measurements and cleaning of the neck. The activity on the neck was 300 kBq before cleaning and 100 kBq afterwards. According to the radiation safety officer, the equivalent dose to the skin of the neck was over 2 Sv. On the basis of the measurements performed at the Radiation and Nuclear Safety Authority, the equivalent dose to the thyroid gland was 27 mSv and the effective dose 1.4 mSv. Because the dose limit for the worker was exceeded, the incident was recorded as an INES scale 2 incident.

In another case, the framing of the image of a dog's abdominal cavity was inadequate, and three fingers of the veterinarian holding the dog were within the radiation beam. The incident caused an effective dose of under 1 μSv to the veterinarian.

Abnormal events in research and industry

In 2018, STUK received reports of 30 abnormal events concerning the use of radiation in industry and research. The reports were related, for instance, to industrial radiography, the use of unsealed sources and detection of radiation sources in a metal recycling process or elsewhere.

Use of radiation in industry

Nine abnormal events related to the use of radiation in industry were reported to STUK in 2018. In five cases, shutters of radiometric gauges had remained open or the source had remained outside the shield. Two cases were related to a damaged radiography imaging room and damaged shield of a sealed source, and an X-ray appliance was stolen in one case.

Example event 1:

A worker taking apart the floor at an industrial plant had pulled a plywood floor board from under the shield of a radiation source, and the shield had moved with the board. The shield had been secured to the floor with bolts, but the attachment bolts were corroded and broke. The worker lifted the shield with the source on top of a silo with the beam of the radiation source pointing downward. Later, another worker received a notification that one surface measurement was not working. This worker lifted the shield back in place. The shutter of the source was open all the time. On the following day, the shutter was closed and the shield was properly secured in place.

Example event 2:
Workers at an industrial plant noticed that a radiometric measuring device was not functioning properly. It was found that the problem was caused by a measurement probe tube that was too short, which caused heating of the radiation source. Because of the heat, the lead lining of the radiation source had melted to such an extent that the shutter of the radiation source was jammed. Because the responsible party immediately contacted STUK and the importer of the radiation appliance, it was possible to develop an overall picture of radiation risks without delay and avoid radiation exposure of workers. The radiation source and shield have been appropriately removed from service.

Example event 3:
A worker had left an X-ray fluorescence analyzer in a locked box in the car in the hotel parking lot. During the night, the car was broken into and the analyzer was stolen. Thanks to eyewitnesses, the police quickly caught the thieves and the analyzer was retrieved within a few hours of the notification.

Industrial radiography

In 2018, STUK received five reports of an abnormal event in industrial radiography. The defects were related to restricting access to controlled area and compliance with instructions.

Example event 1:
A worker was performing radiography in a shielded cabinet, when they noticed that the imaging tube had turned and went to readjust the positioning. Coming back, they noticed that the light exposure was not turned off. The door switch of the cabinet was not intended for the radiography appliance used. In addition, the worker had forgotten to use a dosemeter and radiation alarm. The calculated maximum doses were 8.6 mSv to the hand and 0.35 mSv to the body.

Example event 2:
Workers tried to perform radiographic scans quickly without a working plan. One of the two workers was outside the confined space operating the X-ray equipment, while the other one was inside the space. The worker who was inside went to change the place of the imaging panel in the middle of the procedure, after getting permission from the operator of the X-ray appliance. The operator of the X-ray appliance had forgotten that the exposure was still on. The radiation alarm of the worker inside the confined space went off, and the worker immediately left the area. The dosemeter reading of the exposed worker remained below the recording level.

Use of unsealed sources

In 2018, five abnormal events related to the use of unsealed sources were reported to STUK. The abnormal events concerned the wrong functioning of the transmission line for radioactive gas, slight contamination of working areas and a worker, and exposure of maintenance workers during maintenance. In addition, there were two abnormal events in which the handling of a syringe containing radioactive substance caused a dose to the fingers.

Example event 1:
A sample bottle containing a radiopharmaceutical was shattered, causing contamination in the laboratory. The contaminated areas were identified, after which they were covered with plastic and marked with radiation hazard labels. The contamination of the workers present was measured. The contaminated items and clothes were gathered into plastic bags for halving. No skin contamination was detected in any worker. The incident did not cause any abnormal doses.

Found radiation sources

Of the abnormal events reported to STUK in 2018, eleven were related to found radiation sources or radiating loads detected in a metal recycling process or elsewhere. In three cases, an Am-241 sealed source was melted in a steel manufacturing process. In eight cases, radioactive material was found in scrap metal. In one case, the responsible party had found an unused fluoroscopic appliance in the storage room. The appliance was later sent to be disposed of.

Example event: Several americium sources ended up in the melting process at a steel mill.
Several Am-241 radiation sources ended up in the melting process at a steel mill in 2018. Am-241 radiation sources are very difficult to detect among recyclable metal by measuring, as the energy of the gamma radiation they emit is so low that the surrounding recyclable metal efficiently dampens the radiation. The steel mill has very precise measuring equipment, and they have been able to locate the melted radiation sources by measuring the radiation dose rate from the surface of the transfer ladle pot after the electric arc furnace. In the melting process, americium ends up in the slag, in which a maximum level of approximately 60 000 Bq/kg was measured (the clearance level for americium is 100 Bq/kg). After the melting of all the radiation sources, the mill performed purification melting runs, until the dross was clean. Slag containing americium as well as the combustion gas filters were collected at the factory and stored separately from other materials for final disposal later on. The steel mill has good written instructions for similar incidents. Therefore, none of the mill workers received an additional dose of radiation because of the melting of the radiation sources. After the incident, the mill collected air samples and sent them to STUK for analysis. On the basis of the measurement result and in accordance with the mill's instructions, respiratory filters were worn after the incident, and this was discontinued once the air samples had been analyzed, the purification melting runs had been completed and the respiratory air was found to be clean enough. On the basis of the slag samples collected, the activity of the melted Am-241 source was estimated to be approximately 1–2 GBq in all the melting events. The melted radiation sources came from different batches of scrap metal, which had arrived in Finland via the Netherlands. Scrap metal is shipped to the Netherlands from all over the world, so the real origin of the radiation sources remains unknown. STUK has contacted the Dutch radiation safety authorities, who in turn have contacted those Dutch metal recycling companies through

which the radiation sources had been delivered to Finland. In addition to informing about radiation sources ending up in melting processes, the purpose of this communication is also to encourage Dutch metal recycling companies to perform more precise measurements and use more sensitive radiation meters on all recycled metal to be delivered to Finland (or elsewhere) to prevent similar incidents as efficiently as possible in the future. STUK also reported the incidents to the IAEA. According to STUK's estimate, because of the reoccurrence of the incidents, this is a case of an exceptional safety incident, which means that it is a category 1 event on the INES (International Nuclear Event Scale) scale. STUK has also brought the matter up with European radiation safety authorities.

3 Regulatory control of practices causing exposure to natural radiation

This chapter describes the regulatory control of natural radiation from the ground and related operations.

3.1 Radon at conventional workplaces

The school radon control project continued to monitor radon concentrations at schools. Altogether 1268 schools to be measured were reported to STUK at the beginning of the project in autumn 2016. By the end of 2018, radon measurement results had been received from all but 128 schools.

The authorities responsible for occupational health and safety at the Regional State Administrative Agencies (AVI) reported approximately 150 workplaces to STUK that had not performed radon measurements despite recommendations. STUK took these workplaces under its supervision, sending each one a request for specification and an order to perform radon measurement.

Radon measurements are carried out using alpha track radon detectors provided by STUK and other parties, and the radon concentrations are recorded in the national radon database. Workplace radon concentrations below 400 Bq/m^3 measured with alpha track radon detectors not provided by STUK have been reported to STUK more frequently than before.

The workplace radon monitoring database now contains nearly 2100 workplaces with radon measurements performed in 2018. At these workplaces, 8000 radon concentrations from about 7900 measuring points have been recorded in the radon database. The number of measurements is higher than that of the measuring points, because several measurements were performed at some measuring points. The number of workplaces performing measurements has clearly increased, and one workplace is performing more comprehensive measuring compared with the previous years (Figure 8).

In the radon database, the median for the radon concentrations at conventional workplaces was slightly lower than last year (Figure 9). Approximately 310 workplaces measured at least one radon concentration above the action level (400 Bq/m^3). Of conventional workplaces measured using alpha track radon detectors, approximately 15 per cent had a radon concentration exceeding 400 Bq/m^3 (the action level until 15 December 2018), and approximately 20 per cent had a radon concentration exceeding the new reference value of 300 Bq/m^3.

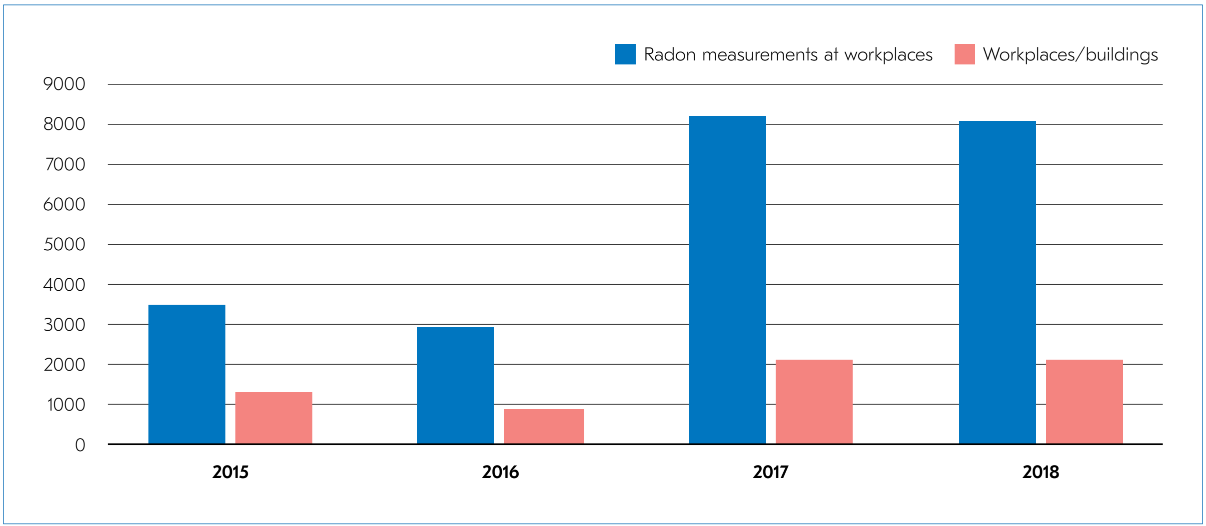

FIGURE 8. Number of workplace measurements/sites recorded in the national radon database, 2015–2018.

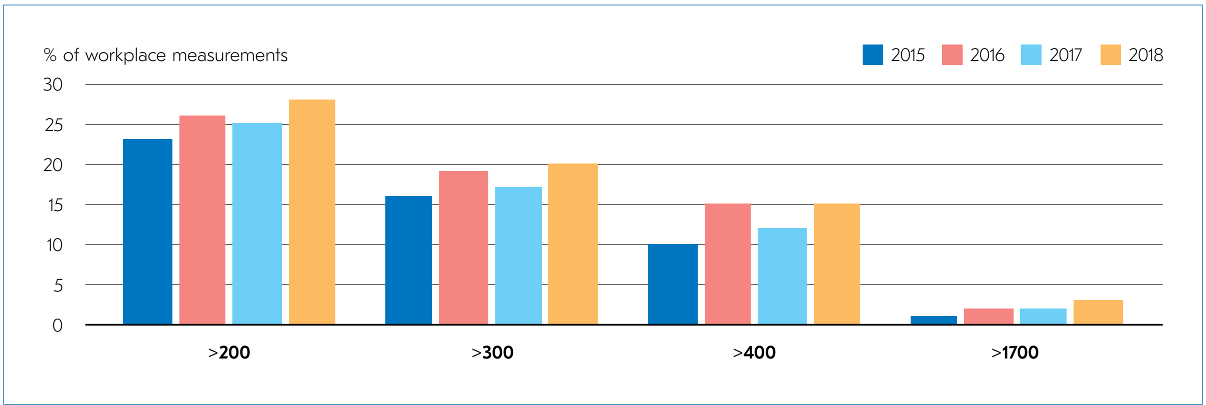

FIGURE 9. Distribution of radon concentrations at workplaces across concentration categories in 2015–2018.

3.2 Radon in underground mines and at excavation sites

STUK inspected radon exposure in underground mines in accordance with the specified goals. The basic inspection interval is two years. In addition, all long-term underground excavation sites reported to STUK pursuant to section 29 of the Radiation Decree were inspected. Workplace radon concentrations were monitored at 14 mines and excavation sites. Radon concentration exceeded 400 Bq/m^3 at one excavation and construction site. STUK issued orders to reduce the radon concentration at these sites. All of the sites succeeded in reducing the radon concentration to below 400 Bq/m^3. In all mines, radon concentrations were found to be below 400 Bq/m^3.

3.3 Radioactivity of construction materials

STUK monitors exposure caused by natural radioactive substances contained in construction materials and other materials. The action level for radiation exposure to the population caused by construction materials used for buildings is 1 mSv a year. Twenty-five decisions were made concerning the radioactivity of construction materials intended for building production. According to the reports submitted to STUK, there were no cases in which the action level was exceeded. Relating to the radioactivity of construction products, a gravel filling memorandum was prepared for the evaluation of radiation caused by a capillary break.

3.4 Radioactivity of household water

The dose caused by long-lived radioactive substances in household water must not exceed 0.1 mSv a year. At two waterworks, the radon concentration of household water exceeded the quality requirements, but the water quality has been brought to a good level. STUK prepared the waterworks sampling programme with Valvira and delivered three lectures on the control of radioactive substances in household water. In addition, guidance was provided to municipal health protection authorities on the phone or by email in questions relating to the radioactivity of household water.

3.5 Regulatory control of other natural radiation

In 2018, STUK carried out three water management-related inspections at Terrafame Oy's Talvivaara mine that involved sampling. In addition, STUK carries out continuous document control of the mining company's in-house control results and required monitoring results and processes other documents submitted for approval. The research plan on radioactive substances in the nature and the update of the water management plan were approved in 2018. Close co-operation in regulatory control has continued with the Kainuu Centre for Economic Development, Transport and the Environment. Three statements were issued relating to the EIA ((environmental impact assessment))of the battery chemicals plant and the safety analysis report on uranium recovery.

In 2018, Terrafame Oy has experienced problems at the Talvivaara mine relating to waters containing uranium, including:

- a leakage resulting from a movement of a tube at the SLS3 basin
- increased uranium concentration in the Kivipuro stream, resulting from runoff water from the construction site in the KL2 waste rock area
- raffinate overflow and blocked pipeline channel
- leakage of primary solution in the middle lane of primary heaps in a membrane-free area because of the breaking of a watering pipe
- increased uranium concentrations in the groundwater pipes of primary leaching.

In connection with the inspection carried out in September after the Kivipuro incident, STUK requested that the water management plan be updated and submitted to STUK for approval, because water had been released outside the mine area through Kivipuro with uranium concentrations exceeding the maximum value. Even though the flow rate and total release were low in the Kivipuro case, what caused concern was the fact that the first person to notice the problem, with a significant delay, was the inspector from STUK who was viewing the documents containing the in-house control results of the mine. The mining company should have responded more quickly to the results of its in-house monitoring. The uranium concentration in Kivipuro quickly returned to the normal level once the necessary measures had been initiated. The implementation of the water management plan will be monitored in the future.

Groundwater in primary leaching is a concern for which measures have been required in co-operation with the Centre for Economic Development, Transport and the Environment. At the end of 2018, the uranium concentration of water in the middle lane wells of the primary leaching area was approximately 2000 µg/l. Compared with 2017, the trend has been more increasing than decreasing. In 2018, an uranium concentration of 100 µg/l was observed for the first time in the groundwater pipe located at the edge of the primary leaching area. Therefore, groundwater assessments and protective measures are required to analyze and prevent the possible spreading of the contamination.

In addition to environmental surveillance, STUK has been involved in the preparation of various statements related to mining operations and provided radiation protection guidelines related to natural radiation.

4 Regulatory control of the use of non-ionizing radiation

4.1 General

"Non-ionizing radiation" refers to ultraviolet radiation, visible light, infrared radiation, radio frequency radiation, and low-frequency and static electric and magnetic fields. Coherent light, or laser radiation, is a special type of visible light. The use of non-ionizing radiation requires a preliminary inspection only in certain special cases, such as the use of high-powered laser equipment in public performances. In other respects, the Non-Ionizing Radiation (NIR) Surveillance Unit of STUK conducts market surveillance of devices and practices that expose the public to non-ionizing radiation.

Market surveillance is targeted at the following services:

- sunbed services
- consumer laser devices
- wireless communication devices and high-powered radio transmitters causing public exposure
- cosmetic treatment devices that utilize non-ionizing radiation and their use in services.

In addition to regulatory control, STUK issues instructions on the application of the recommended values of low-frequency electric and magnetic fields, stipulated by the Ministry of Social Affairs and Health Decree 294/2002, to uses such as power lines, and approves the methods and instructions used in the inspection and regulatory control of the radio and radar devices used by the Finnish Defence Forces.

The work of the NIR Unit in regulatory control of the use of non-ionizing radiation in 2009–2018 is shown in Tables 13–16 of Appendix 1. Some dangerous laser devices were found, in particular laser pointers have been available in the market more frequently than during the previous year. In 2018, STUK intervened 45 times in the sale of a dangerous device and three times in the unlicensed use of an effect laser. Similar to previous years, STUK received a number of requests for official statements and information requests related to electromagnetic fields from the authorities. In particular, STUK received several requests for statements on power line projects.

Regulatory control of non-ionizing radiation particularly focused on providers of sunbed services. Many shortcomings were still detected that affect safety. Regulatory control of radiation practices in the beauty care industry focused on powerful laser equipment.

The increased online trade with consumers ordering products directly from outside the EU poses a challenge to the regulatory control of consumer products. In addition, the prices of products such as high-powered laser equipment have decreased considerably as a result of the advancement of technology. In many product categories, traditional branded products are accompanied by cheap non-branded models. STUK monitored the situation actively and noticed that dangerous laser pointers were frequently found again. Nearly half of the removal requests to online auctions were made to one citizen who repeatedly tried to sell five overly strong laser pointers.

In addition to carrying out regulatory control, STUK promotes the reduction of the harmful effects of phenomena such as UV radiation through active communication. Concerns related to mobile phone base stations and wireless networks have been particularly apparent in citizens' inquiries and information requests to STUK.

4.2 Regulatory control of UV radiation devices

Regulatory control of sunbed devices and facilities is carried out in co-operation with the municipal health protection authorities under the amendment to the Radiation Act that entered into force on 1 July 2012, prohibiting the use of sunbeds from under 18-year-olds. Health inspectors audit the facilities as part of the regulatory control pursuant to the Health Protection Act and submit a report on their findings to STUK for decision-making. In addition, STUK carries out its own inspections where necessary.

The transition period for the amendment (section 44 of the Radiation Act) that prohibited self-service sunbed facilities ended already on 1 July 2015. In 2018, non-compliance with the requirement was still frequently detected, and enhanced regulatory control was continued. Altogether 30 inspections of sunbed facilities were carried out by municipal health protection authorities. In addition to this, five sunbed facilities were surveyed on the basis of STUK's own monitoring (Appendix 1, Table 15). Altogether on-site inspections of sunbeds were carried out, including the inspections performed by municipal health protection authorities. No deficiencies were detected in 47 per cent of the facilities inspected by the health protection authorities. In 27 per cent of the supervised facilities, the responsible person required by law was not present during all hours of use of the sunbed equipment. Deficiencies relating to instruction manuals were detected in 27 per cent of the facilities and problems related with timers in 17 per cent.

4.3 Regulatory control of laser devices

The regulatory control of laser devices designed for private use is divided into market surveillance of traditional and online sales. In addition, the use of high-powered laser equipment in public performances is subject to regulatory control.

In connection with market and on-site surveillance, STUK intervened in the sale or use of 45 laser devices. These cases were related to the selling of a laser device on a website for trade between consumers.

STUK received 52 notifications on the use of laser equipment in public shows. STUK inspected 15 of these performances on site. In the inspections, the safety arrangements and the pointing of the laser beams were mainly found to comply with the requirements. In one show, the operator gave up on the idea of using effects pointed towards the audience because of the safety issues detected in the inspection. In one case, the operating plan for lasers pointing to the sky was so inadequate that a reminder letter concerning the issue was sent to the responsible party. The show was nevertheless arranged, as the responsible party delivered appropriate plans. Eight fixed-term approvals were in force at the end of 2018. The approvals were granted while the previous Radiation Act was in force. Therefore, they may remain valid up to the end of 2020.

4.4 Regulatory control of devices producing electromagnetic fields

In 2018, STUK did not test wireless communications devices in connection with its market surveillance, but instead of it, STUK initiated a comparison measurement campaign in co-operation with the Swedish radiation protection authority (SSM). The exposure caused by ten mobile phones will be measured during the campaign. SSM carried out the measuring of mobile phones in 2018, and STUK will perform the measurements in 2019. The results of the measurements will be posted on STUK's website.

Mobile phone base stations were monitored through preliminary safety analyses based on reports from citizens. All base stations were found to be safe and installed in a compliant manner. Stronger than normal radiation was detected at one base station, but also in this case the result of measurement remained clearly below the exposure limit values. However, the operator managing the base station informed that they will reorientate the antenna.

4.5 Regulatory control of cosmetic NIR applications

The extensive campaign for the regulatory control of companies providing cosmetic treatments, initiated in 2016, continued in 2018. The regulatory control was targeted at strong laser devices and their use. STUK found out about them particularly through denunciation received. Two responsible parties voluntarily stopped using tattoo removal lasers after STUK had contacted them. With respect to RF treatment devices using radio frequency radiation, it was known that the limit values for exposure would clearly increase from what they were before. Therefore, instead of regulatory control, the focus was on the development of control methods, standardization work concerning the devices and providing information on the law reform. For instance, importers and users of the devices who have contacted STUK have asked about the safety requirements related to the use of devices before purchasing or selling a device.

STUK actively informed operators in the industry about the proposed amendments to legislation, as these will have a significant effect on the industry. Stricter provisions were included in law, such as the obligation to inform customers about the risks of a procedure, the consideration of contraindications and the inclusion of new radiation techniques in the law. On the other hand, some regulations were made less strict, taking into account the needs of the responsible parties without endangering customer safety.

4.6 Other tasks

STUK received a number of requests for statements on power line projects and land use plans near power lines. Altogether seven statements were issued on projects. Four statements were issued on other matters related to non-ionizing radiation.

In addition to regulatory control, STUK's NIR unit replied to 496 citizen inquiries in 2018. Of these inquiries, 216 were made by telephone and 280 via email. In particular, these inquiries concerned radiation related to mobile phones, base stations and power lines as well as household electrical equipment and wiring. Many inquiries also concerned laser equipment and UV radiation.

4.7 Abnormal events

In 2018, STUK received three notifications of events caused by non-ionizing radiation that required immediate action. An online store selling leisure time products was selling a laser pointer for the hardening of UV glues. According to the measurements performed by STUK, the power of the pointer was 35 times the acceptable value. After STUK contacted the store, the products were immediately withdrawn from the outlet and the online store.

In another abnormal event, a STUK inspector noticed that laser equipment was in use in a café. On the basis of the inspection performed, one of these lasers was a class 3B device without STUK's permission for use. In connection with the inspection of the case, the café voluntarily stopped using the class 3B device on the premises.

In the third case, STUK was informed about a provider of sunbed services with overly powerful lamps. The measurement performed by STUK revealed that the lamps of the sunbed appliance were the strongest in STUK's recorded history. The responsible party changed the lamps to acceptable ones. STUK has not received reports on damage caused by the overly powerful lamps.

The numbers of abnormal events in 2009–2018 are shown in Figure 3 (item 1.1; see also item 2.9 on abnormal events in the use of ionizing radiation).

5 Regulation work

The EU's radiation safety directive (2013/59/Euratom, BSS Directive) was approved on 5 December 2013 and entered into force in the national legislation of Finland on 15 December 2018. The new Radiation Act and the lower level statutes issued under it implement the requirements of the EU's radiation safety directive concerning ionizing radiation and revise the provisions concerning non-ionizing radiation. The government proposal also involves amendments to a number of associative laws. The key principle of the revision is to concentrate regulatory control more accurately on areas with the highest radiation risks. The new Act will provide a new framework for the safe use of radiation. Those requirements that are significant for society and restrict the rights of individuals were transferred to the new Act in the manner required by the Constitution. Provisions on less significant matters are laid down in decrees, and provisions on the authorities' rights to issue regulations are precisely and clearly defined.

Government proposal for the new Radiation Act was submitted to the European Commission for an advance statement at the beginning of September 2017. After this, the proposal was finalized by public officials at STUK and the Ministry of Social Affairs and Health. Pursuant to the proposed Act, one government decree and two decrees of the Ministry of Social Affairs and Health were also prepared. In addition, seven STUK Regulations were prepared pursuant to the proposed Act that were sent out for external comments in 2017 and 2018. The other Regulations are expected to be completed early in 2019.

The comprehensive revision of radiation legislation was a very extensive project and required co-operation between different ministries and the fields they represent. The participants of the revision work include experts from ministries, national boards, labour market organizations, training organizations and parties running a radiation practice (responsible parties), more than 100 people altogether.

6 Research

The objective of STUK's research activities is to produce new information on the occurrence and measuring of radiation, the harmful effects of radiation and their prevention, and the safe and optimal use of radiation sources and radiation use methods. Research supports the regulatory and metrological activities of STUK and the maintenance of emergency preparedness.

A further purpose of research related to the uses of radiation is to increase knowledge and expertise in this field and to ensure reliable measurement of radiation. Research on ionizing radiation is mainly related to medical uses of radiation. There is a continuous need for research because of the rapid progress of examination and treatment methods. Research on non-ionizing radiation focuses on the exposure determination methods necessary for regulatory control and the development of regulations.

STUK has been active in its efforts to expand the pool of competence in Finnish radiation safety research.

In October 2015, STUK and nine Finnish universities established a consortium for radiation safety research coordinated by STUK. At the same time, a national radiation safety research programme was developed. The programme was updated in 2018. STUK works as part of the Helsinki Institute of Physics. Through this co-operation, STUK is a member of the Knowledge Transfer for Medical Applications group of the European Organization for Nuclear Research (CERN). Finnish university and university hospital partners have been encouraged to take part in international research consortia and funding application processes related to radiation safety and radiation metrology.

Research and development projects

STUK participated in the work of the EURADOS working groups 2 (Harmonization of individual monitoring), 7 (Internal dosimetry), 9 (Radiation dosimetry in radiotherapy) and 12 (Dosimetry in medical imaging). EURADOS research focused on patient exposure in interventional radiology and cardiology. The project, coordinated by STUK, analyzed patient exposure in 13 countries and made a proposal for European radiation exposure reference levels for the use of radiation in cardiology. The results were published in 2018. The results of the research project concerning the skin exposure of patients and the alarm thresholds were also published in 2018. A project to analyze the total dose caused by radiotherapy (incl. imaging) was prepared in collaboration between EURADOS and EFOMP. STUK participates in the computational determination of patient doses as well as the development of risk level calculation methods and coordinates the project.

STUK surveyed public exposure to electric and magnetic fields in different environments of use and on different applications. Undergrounds and trains are examples of the environments. As regards applications, the radiation safety of magnetic mattresses and electric blankets was surveyed. Exposure caused by base stations in citizens' homes was measured in a small-scale campaign.

STUK surveyed public exposure to electromagnetic fields from amateur radio stations in 2017 and 2018. The results will be published as a STUK TR report in 2019.

STUK continued the project launched in 2017 to develop a measurement method for RF beauty care devices. The research has provided new data on the linking of RF radiation to the human body, which will improve the exposure value and the safe use of the devices can be more accurately specified. The objective is to write a scientific article on the development of the measurement method in 2019. At the same time, the research data obtained is used on the IEC's ongoing standardization project that will specify the highest acceptable exposures for RF treatment devices, among other things.

The ERASMUS+ funded EBreast project participated by STUK ended in 2018. Its main objective was to survey and develop the training of personnel participating in the treatment chain of breast cancer, from early diagnosis to follow-up. STUK was responsible for the improvement of radiation safety and quality assurance skills in screening mammography and clinical mammography. The educational material produced by the project can be found on the internet at http://www.earlydetectionofbreastcancer.com/

STUK assessed doses to the eye in a group of employees exposed to radiation in nuclear medicine. The assessments were carried out using thermoluminescence. The results will be used in practical radiation surveillance and the radiation protection of personnel. The measurements were completed in 2017. The results will be published in 2019.

The four-year detector development project, funded by the Academy of Finland, continued in 2018. The work is carried out in co-operation with the Helsinki Institute of Physics. The project develops position-sensitive detectors that identify the type of radiation. They are developed to respond to the needs of diagnostic radiation practices and radiotherapy dosimetry. The detectors can also measure the radiation energy spectrum.

STUK and Helsinki University Hospital have collaborated to survey the exposure of workers in medical use of radiation and the probability of potential exposure. The results were published in 2018.

Demand for neutron measurement and irradiation has increased. STUK carried out simulations and measurements to analyze the suitability of its irradiation hall for the calibration of personal dosemeters with neutron radiation. The results were published in 2018. In connection with the project, a Nordic comparison of neutron meters was performed. The results will be presented at the Nordic radiation protection conference in summer 2019.

Together with Finnish specialists, STUK prepared and published a guide for the use of radiation in cardiology.

As part of the activities of EURAMET TC-IR, STUK has participated in the updating of the association's research roadmap. STUK has also participated in the updating of EURDOS' research strategy (medical use of radiation).

European Metrology Programme for Innovation and Research EMPIR

A three-year project on perfusion imaging dosimetry was launched in summer 2016. STUK participates in the development of patient-specific CT dosimetry in co-operation with PTB from Germany and the University of Helsinki. The project has developed measurement and computational methods for the determination of patient doses for CT scans. The results have been presented in a workshop arranged in Copenhagen in summer 2018, and results have also been sent to be published in newspapers.

On the RTNORM project, STUK develops dosimetry for ionization chambers used for dose determination in radiotherapy. The project is related to the update of the IAEA protocol for dose measurement in radiotherapy (IAEA TRS 398).

The MetroRADON project, launched in 2017, continued. The objective is to improve the accuracy of radon calibrations across Europe.

7 International co-operation

Participation in the work of international organizations and commissions

Representatives of the Department of Radiation Practices Regulation are involved in a number of international organizations and commissions dealing with the regulatory control and the development of safety instructions and measuring methods relating to the use of ionizing and non-ionizing radiation, and in standardizing activities in the field of radiation. These organizations and commissions include IAEA, NACP, EURADOS, EURAMET, ESTRO, ESOREX, AAPM, IEC, ISO, CEN, CENELEC, ICNIRP, EAN, EUTERP, HERCA, EURATOM/Article 31 Group of Experts, WHO, UNSCEAR.

Participation in meetings of international working groups

In 2018, representatives from STUK participated in the meetings of the following international organizations and working groups:

- EURAMET (European Association of National Metrology Institutes) annual meeting of contact persons
- Meeting of the Nordic Dosimetry Group
- Meeting of the group on the use of radiation in Nordic health care sector (Nordic group for medical applications)
- HERCA (Heads of the European Radiological Protection Competent Authorities) and its working groups
- The annual meeting of EURADOS (European Radiation Dosimetry Group) and its working groups
- NORGIR meeting (Nordic Working Group on Industrial Radiation)
- EACA meeting (European Association of Competent Authorities on the transport of radioactive material)
- ICNIRP (International Commission on Non-Ionizing Radiation Protection)
- NACP Radiation Physics Committee
- Nordic Ozone Group (incl. UV matters)
- NIR seminar of the Nordic radiation protection authorities in Oslo
- WHO EMF project and InterSun Programme; international advisory group
- IEC TC 61 MT 16 meeting (including sunbed standards)
- IEC TC 76 meeting (optical radiation and laser equipment)
- IEC PT 60335-2-115 online meetings (standardization of beauty care appliances)
- IAEA: Transport Safety Standards Committee
- IAEA: Radiation Safety Standards Committee

- CERN: Knowledge Transfer for Medical Applications
- Meeting of the ESOREX (European Platform on Occupational Radiation Exposure) working group
- Meeting of Nordic radiation protection authorities in Stockholm on the implementation of EU-BSS.
- ESOREX (European Platform on Occupational Radiation Exposure) työryhmän kokous

8 Co-operation in Finland

Participation in the work of Finnish organizations and commissions

Representatives of STUK are involved in many Finnish organizations and commissions that deal with the regulatory control and research of the use of ionizing and non-ionizing radiation, and with standardization activities in the field of radiation. These include the Advisory Committee on Metrology, the Radiation Safety Conference Committee, the Education Committee of Medical Physicists, Eurolab-Finland, SESKO and the Finnish Advisory Committee for Clinical Audit (KLIARY) funded by the Ministry of Social Affairs and Health and appointed by the National Institute for Health and Welfare, the Screening Committee, the authorities' radon working group and the Environmental Intolerance Network. STUK experts take part in several meetings in the field of radiation safety in Finland every year, giving presentations and lectures.

Participation in meetings of Finnish working groups

In 2018, representatives from STUK participated, among others, in the meetings of the following Finnish organizations and working groups:

- Subordinate working groups of the Ministry of Social Affairs and Health for the comprehensive revision of radiation legislation
- The Screening Committee of the Ministry of Social Affairs and Health and its subordinate working group preparing the decree amendment.
- Environmental Intolerance Network of the Ministry of Social Affairs and Health
- SESKO SK 34 committee (luminaires)
- SESKO SK 61 committee (safety of domestic electrical appliances)
- SESKO SK 106 committee (electromagnetic fields)
- The Radiation Safety Committee of the Finnish Defence Forces (NIR matters)
- The Education Committee of Medical Physicists (radiation protection matters).
- The RDI coordination group of the administrative branch of the Ministry of Social Affairs and Health

Finnish conferences arranged by STUK

At the Radiation Safety Conference arranged by STUK on May 23–25 2018, representatives from different industries discussed the changes to be brought about by the Radiation Act reform. In addition, STUK participated in the arrangements of the Sädeturvapäivät radiation safety days.

Other co-operation in Finland

A STUK representative served as a member and secretary on the Finnish Advisory Committee for Clinical Audit (KLIARY), appointed by the National Institute for Health and Welfare (THL) and funded by the Ministry of Social Affairs and Health (STM). The STUK representative is also responsible for the maintenance of the group's website. The activities of the group included preparing a recommendation concerning advanced clinical audits of small units performing X-ray examinations. The recommendation was published in January 2018. Some previously published recommendations were updated. Recommendations and more information about the group's activities are available on the group's website (www.kliininenauditointi.fi).

9 Communication

In 2018, STUK received a number of radiation-related questions through its website and by phone from citizens, radiation users, the media and other parties interested in radiation. Most of the questions were related to non-ionizing radiation. Several interviews on current radiation topics were given to the media.

Press releases and online news articles were prepared by the staff of the Radiation Practices Regulation Department with the following headings:

- STUK regulation improves the radiation safety of cosmetic treatments
- STUK's radon mitigation training in Kouvola on 5 February 2019
- In December, STUK's website contains information compliant with the old and the new Radiation Act
- Binding STUK regulations supplement the Radiation Act
- A radiation source that travelled from Helsinki to Eurajoki among scrap remained inside its shielding without causing danger
- The owner of the radiation source found among scrap metal on Friday was identified
- The new Radiation Act highlights the responsibility of responsible parties – activities and control become risk-based
- Less than a week left to enrol in the Cores symposium on non-ionizing radiation research
- Few consider radon a risk to their health
- Three radioactive americium sources end up in melting in Tornio within short period of time
- The new Radiation Act includes stricter radon measurement obligations for employers
- It is possible to buy a dangerous laser device on the internet
- Don't barbecue your skin at music festivals!
- Animal attendant's skin accidentally contaminated with radioiodine
- Enhanced monitoring by STUK: High radon concentrations at workplaces also outside radon risk areas
- Tommi Toivonen appointed as Director of the Radiation Practices Regulation department at STUK.

Two newsletters were published in 2018 for radiation users in the health care sector and two newsletters for users in industry. The objective is to make the newsletter an integral part of communication.

10 Metrological activities

10.1 General

STUK serves as the national metrological laboratory for radiation dose quantities. STUK maintains national and other measurement standards to ensure the accuracy and traceability of radiation measurements carried out in Finland. STUK calibrates its own standards at regular intervals at the International Bureau of Weights and Measures (BIPM) or other primary laboratories. In the field of radiation metrology, STUK is involved in the work of the Advisory Committee on Metrology and the European Association of National Metrology Institutes (EURAMET). With respect to dose quantities, STUK also participates in the international equivalence agreement (CIPM–MRA), the implementation of which is coordinated in Europe by EURAMET, and in the network of secondary standard dosimetry laboratories (SSDL), which is jointly coordinated by IAEA and WHO.

Metrological activities are the responsibility of STUK's Radiation Metrology Laboratory for ionizing radiation and the NIR Unit for non-ionizing radiation. Metrology of ionizing radiation activity quantities is the responsibility of the Department of Environmental Radiation Surveillance and Emergency Preparedness (VALO) at STUK.

Irradiation equipment and national metrological standards were maintained for calibrations of radiation meters for radiotherapy, radiation protection and X-ray imaging. The standards laboratory of radon has still been used for radon meter calibration and research alike.

10.2 Meter and measurement comparisons

The results of four measurement comparisons were published in which STUK has participated in previous years. These comparisons were performed on photon radiation and different X-radiation types. STUK's results were excellent in all comparisons, efficiently supporting STUK's calibration activities. In 2018, STUK participated in a comparison performed on beta radiation. The results of this comparison will be published later.

In addition, STUK participated in the dosimetry comparisons (RPLD and OSLD comparisons) arranged by the IAEA/WHO calibration laboratory network. STUK's results were well within the acceptable range; thus, the results efficiently support STUK's calibration activities (Figure 10).

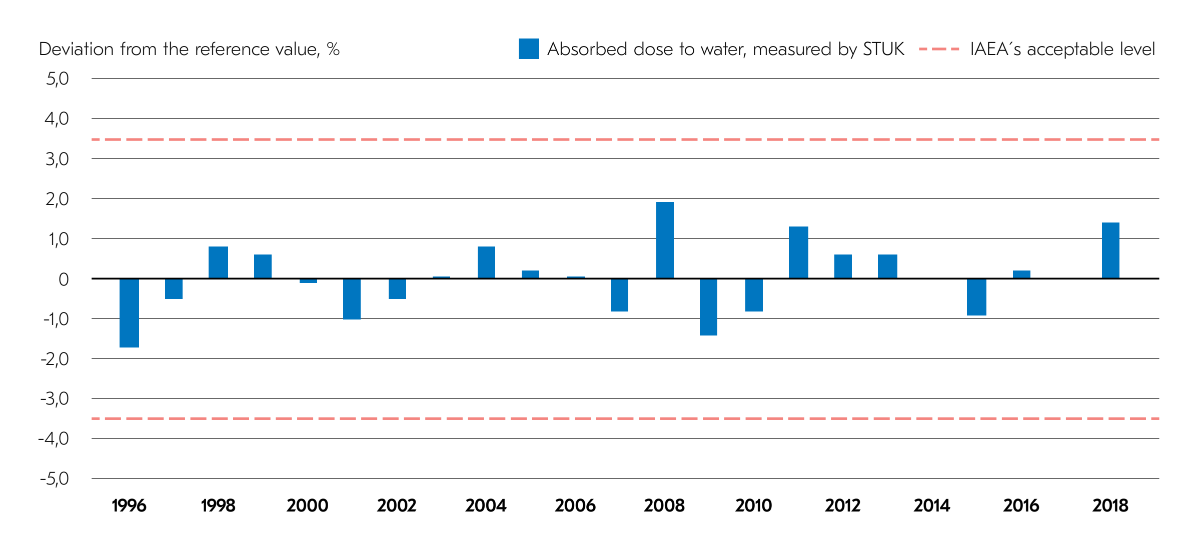

FIGURE 10. The results of IAEA dosimetry comparisons in which STUK has participated in 1996–2018

11 Services

11.1 Calibration, testing and irradiation

STUK performed radiation meter calibrations and testing according to demand. The dosimetry laboratory performed 465 radiation meter calibrations and irradiated 1851 samples. Approximately 30 per cent of the calibrations were performed on STUK's own instruments.

The standard laboratory of radon performed nearly 50 radon meter calibrations.

The Non-Ionizing Radiation Surveillance Unit performed a total of five radiation meter calibrations and tests, along with four safety assessments and radiation measurements. The service output of the NIR Unit from 2009 to 2018 is shown in Table 14 of Appendix 1.

11.2 Other services

Altogether 42 copies of the PCXMC computer application designed for calculating patient doses in X-ray diagnostics were sold.

Appendix 1
Tables

TABLE 1. Radiation practices in the use of radiation in health care and veterinary practices at the end of 2018.

Use of radiation	Number of practices
X-ray practices	311
Veterinary X-ray practices	248
Challenging X-ray practices	95
C-arm practices	76
Small-scale X-ray practices	1 385
X-ray practices outside X-ray departments	50
Screening with X-rays	49
Use of unsealed sources	25
Use of unsealed sources (veterinary)	2
Use of sealed sources	25
Use of sealed sources (veterinary)	1
Radiotherapy	14

TABLE 2. Radiation sources and appliances and radionuclide laboratories in the use of radiation in health care and veterinary practices at the end of 2018.

Appliances/Sources/Laboratories	Number
X-ray diagnostic appliances (generators)*)	**1604**
fixed conventional X-ray appliances	482
portable fluoroscopy appliances	289
portable conventional X-ray appliances	156
mammography appliances, of which	156
• screening mammography	80
• tomosynthesis	16
fixed fluoroscopy appliances, of which	108
• angiography	49
• fluoroscopy	24
• cardioangiography	48

Appliances/Sources/Laboratories	Number
CT-appliances, of which	141
• SPECT-CT	37
• PET-CT	13
CBCT appliances (other than dental imaging)	17
O-arm appliances	10
dental X-ray appliances (other than conventional dental imaging), of which	178
• CBCT appliances	120
• panoramic tomography X-ray appliances	111
• intraoral X-ray appliances	28
bone mineral density measurement appliances	49
other appliances	3
Dental X-ray appliances (conventional dental X-ray practices)	**6034**
intraoral X-ray appliances	5392
panoramic tomography X-ray appliances	642
Radiotherapy appliances	**125**
accelerators	48
X-ray imaging appliances	52
automatic afterloading appliances	7
manual afterloading appliances	1
X-ray therapy appliances	1
radiotherapy simulators	16
sealed sources (check sources)	40
Sealed sources	**334**
calibration and testing equipment	324
attenuation correction units	5
gamma irradiators	0
other sealed sources in health care	5
X-ray appliances in veterinary practices	**469**
conventional X-ray appliances	323
fluoroscopy appliances	1
intraoral X-ray appliances	134
CBCT appliances	3
CT appliances	8
other appliances	0
Radionuclide laboratories	**36**
Type B laboratories	28
Type C laboratories	8

*) An X-ray diagnostic appliance comprises a high voltage generator, one or more X-ray tubes and one or more examination stands.

TABLE 3. Radiation practices in the use of radiation in industry, research and education at the end of 2018.

Use of radiation	Number of practices
Use of X-ray appliances	689
Use of sealed sources	546
Installation, test operations and servicing	238
Import and export of radioactive materials or trade in them	111
Use of unsealed sources	75
Trade in X-ray appliances	37
Use of particle accelerators	18

TABLE 4. Radiation sources and appliances and radionuclide laboratories in the use of radiation in industry, research and education at the end of 2018.

Appliances/Sources/Laboratories	Number
Appliances containing radioactive materials	**5 832**
level switches	1 740
continuous level gauges	1 121
density gauges	964
weight scales	621
basis weight meters	462
appliances or sources used for calibration, testing or education	424
moisture and density gauges	103
particle analyzers	78
radiography appliances	37
fluorescence analyzers	35
other appliances	247
X-ray appliances	**2 132**
fluoroscopy appliances	897
diffraction and fluorescence analyzers	620
radiography appliances	410
basis weight meters	48
other X-ray appliances	157
Accelerators	**28**
research	15
fluoroscopy	7
manufacturing of radioactive materials	6

Appliances/Sources/Laboratories	Number
Radionuclide laboratories *)	**97**
Type A laboratories	14
Type B laboratories	21
Type C laboratories	60
activities outside laboratories (tracer element tests in industrial plants)	2

*) According to the classification in old legislation

TABLE 5. Radionuclides most commonly used in sealed sources in industry, research and education at the end of 2018.

Radionuclide	Number of sources
Other than high-activity sealed sources	
Cs-137	4 128
Co-60	904
Am-241 (gamma sources)	315
Kr-85	304
Fe-55	104
Am-241 (AmBe neutron sources)	98
Sr-90	97
Ni-63	94
Pm-147	84
High-activity sealed sources	
Cs-137	28
Co-60	14
Am-241 (gamma sources)	10
Ir-192	9
Am-241 (AmBe neutron sources)	6
Pu-Be	1
Se-75	1

TABLE 6. Deliveries of sealed sources to and from Finland in 2018

Radionuclide	Deliveries to Finland		Deliveries from Finland	
	Activity (GBq)	Number	Activity (GBq)	Number
Ir-192	65 933	27	6 419	27
Se-75	5 180	2	533	2
Kr-85	1 863	118	1 110	75
Ni-63	183	497	4	38
Fe-55	130	23	67	12
Cs-137	126	109	3	6
Pm-147	37	4	20	10
Gd-153	10	15	- *)	-
Co-57	6	40	-	-
Am-241	5	183	6	1047
Co-60	1	17	-	-
Ge-68	1	23	-	-
Sr-90	< 1	2	2	5
C-14	-	-	4	12
others total **)	< 1	18	< 1	1
Total	**73 477**	**1078**	**8 169**	**1 235**

*) The symbol "-" indicates no deliveries from Finland.
**) Deliveries to Finland: Po-210, Ba-133, I-125 and Ra-226.
Deliveries from Finland: Ba-133.

TABLE 7. Manufacturing of radioactive substances (unsealed sources) in Finland in 2018.

Radionuclide	Activity (GBq)
F-18	269 301
O-15	27 424
C-11	26 941
Ga-68	45
Total	**323 710**

TABLE 8. Number of air crew members subject to individual monitoring of radiation exposure and total dose of crew members (sum of effective doses) in 2014–2018.

Year	Number of workers		Total dose (Sv)	
	Pilots	Cabin crew	Pilots	Cabin crew
2014	1 213	2 441	2,74	5,93
2015	1 153	2 527	2,66	6,09
2016	1 118	2 534	2,95	7,24
2017	1 239	2 717	3,25	8,36
2018	1 306	3 042	3,68	9,86

TABLE 9. Number of radiation workers subject to individual monitoring by sector in 2014–2018.

Year	Number of workers in each sector								
	Health care		Veteri-nary practices	Industry	Research and edu-cation	Manu-facturing of radi-oactive materials	Others*)	Use of nuclear energy**	Total***)
	Exposed to X-radia-tion	Exposed to other radiation sources							
2014	3 743	1 243	653	1 257	686	22	143	3 621	11 197
2015	3 631	1 244	664	1 371	649	26	142	3 291	10 800
2016	3 548	1 218	703	1 322	644	27	163	3 511	10 951
2017	3 222	1 184	726	1 420	685	34	159	4 144	11 381
2018	3 106	1 254	762	1 439	647	31	168	4 794	12 002

*) Sectors included: installation/servicing/technical test runs, trade/import/export and services.

**) Finns working at nuclear power plants in Finland and abroad and foreign workers working at Finnish facilities.

***) The figures shown on a certain row of this column is not necessarily the same as the sum of figures in other columns of the same row, as some health care staff are exposed both to X-radiation and other radiation sources, and there are workers in industry who are also engaged in the use of nuclear energy.

TABLE 10. Total doses (sums of Hp(10) values) to workers subject to individual monitoring in 2014–2018.

Year	Total dose (Sv)								
	Health care		Veterinary practices	Industry	Research and education	Manufacturing of radioactive materials	Others*)	Use of nuclear energy**	Total***)
	Exposed to other radiation sources	Muille säteilylähteille altistuvat							
2014	1,29	0,08	0,11	0,16	0,04	0,019	0,007	1,57	3,28
2015	1,27	0,10	0,13	0,18	0,03	0,011	0,003	1,35	3,07
2016	1,22	0,08	0,13	0,16	0,04	0,016	0,007	1,81	3,46
2017	1,04	0,09	0,14	0,18	0,03	0,024	0,003	1,53	3,04
2018	1,01	0,10	0,13	0,16	0,02	0,030	0,010	2,37	3,83

*) $H_p(10)$ values are generally (sufficiently accurate) approximations of the effective dose. An exception to this is the use of X-radiation in health care and veterinary practices in which workers use personal protective shields and in which the dose is measured by a dosemeter on the exposed side of the shield. The effective dose is then obtained by dividing the $H_p(10)$ value by a factor between 10 and 60.
**) Sectors included: installation/servicing/technical test runs, trade/import/export and services.
***) Finns working at nuclear power plants in Finland and abroad and foreign workers working at Finnish facilities.

TABLE 11. Data (Hp (10) values) on certain occupational groups in 2018.

Group	Number of workers	Total dose (Sv)	Average dose (mSv)		Highest dose (mSv)
			Workers whose dose exceeds recording	All workers subject to individual monitoring	
Cardiologists and interventional cardiologists**)	213	0,40	2,6	1,9	14,5
Interventional radiologists**)	36	0,24	8,7	6,8	40,3
Radiologists**)	260	0,21	3,3	0,8	14,8
Consultant specialists**) ***)	277	0,05	1,1	0,2	6,7
Radiographers (X-radiation)**)	947	0,03	0,6	0,0	2,7
Radiographers (other than X-radiation)	621	0,07	0,7	0,1	4,7
Animal attendants and assistants**)	476	0,07	1,0	0,2	4,0
Veterinarians**)	289	0,06	1,6	0,2	6,5
Industrial material inspection technicians****)	612	0,12	0,8	0,2	4,2
Industrial tracer testing technicians	28	0,04	2,4	1,3	6,8
Nuclear power plant workers					
• insulation work	121	0,29	4,8	2,4	14,0
• mechanical work and machine maintenance	1040	0,68	1,4	0,7	10,0
• cleaning	291	0,25	1,9	0,9	10,2
• material inspection	349	0,26	1,2	0,7	11,2
• electrical and automation work	777	0,17	0,9	0,2	7,8
• radiation protection personnel	98	0,18	2,3	1,9	11,6
• scaffolding and haulage work	194	0,19	1,6	1,0	10,0

*) Recording level is 0.10 mSv per month or 0.30 mSv per 3 months.
**) $H_p(10)$ values are generally (sufficiently accurate) approximations of the effective dose. The doses to these worker groups are an exception. Workers engaged in the use of radiation (X-rays) in health care and veterinary practices use personal protective shielding, and the dose is measured by a dosemeter on the exposed side of the shield. The effective dose is then obtained by dividing the $H_p(10)$ value by a factor between 10 and 60.
***) Including surgeons, urologists, orthopaedists, neuroradiologists and gastroenterologists.
****) Exposure arising elsewhere than in a nuclear power plant.

TABLE 12. The most significant radioactive waste in the national storage facility for low-level waste (31 December 2018).

Nuclide	Activity [GBq] or mass
H-3	32184
Cs-137	2698
Am-241	2195
Pu-238	1482
Kr-85	1413
Am-241 (Am-Be)	602
Ra-226	235
Sr-90	203
Cm-244	132
Co-60	70
Pm-147	45
Ni-63	34
Fe-55	19
C-14	18
Pu-238 (Pu-Be)	7
Ra-226 (Ra-Be)	1
U-238 (depleted uranium)	1470 kg
Th-232	2,5 kg

TABLE 13. Work of the NIR Unit in regulatory control of the use of non-ionizing radiation in 2009–2018.

Year	Regulatory inspections	Decisions	Statements	Prohibitions of dangerous laser equipment sold on the internet	Total
2009	47	2	9	15	73
2010	55	3	9	31	98
2011	56	6	3	42	107
2012	53	0	15	43	111
2013	63	3	11	42	119
2014	53	2	23	41	119
2015	68	1	14	14	97
2016	72	2	10	18	102
2017	81	3	11	22	117
2018	56	0	10	45	111

TABLE 14. Service work of the NIR Unit in 2009–2018.

Year	Calibrations and tests	Safety assessments and radiation measurements	Total
2009	31	12	43
2010	36	13	49
2011	4	10	14
2012	8	16	24
2013	5	5	10
2014	6	8	14
2015	2	7	9
2016	8	4	12
2017	6	3	9
2018	5	4	9

TABLE 15. Inspections of sunbed facilities in 2009–2018. In addition to STUK's own inspections in 2012–2018, decisions on sunbeds were also made on the basis of inspections reported by health inspectors of municipalities (number in brackets) for decision-making. Compliance with the requirements was inspected by sending requests for specification.

Year	Number of inspections
2009	19
2010	16
2011	7
2012	6 (16)
2013	3 (40)
2014	1 (20)
2015	4 (17)
2016	4 (55)
2017	6 (31)
2018	5 (30)

TABLE 16. SAR tests of mobile phones and other wireless devices in 2009–2019.

Year	Number of tests
2009	15
2010	10
2011	5
2012	15
2013	11
2014	10
2015	14
2016	11
2017	0
2018	0

Appendix 2
Publications in 2018

The electronic publication archive Julkari (julkari.fi) features STUK's serial publications in PDF format. Julkari also serves as a publication register. For this reason, only metadata is available for some publications.

The following publications concerning safe use of radiation were completed in 2018

Scientific articles by STUK employees

Bjerke H, Plagnard J, Bordy JM, Kosunen A, Huikari J, Persson L, Hetland PO. Comparison of the air-kerma x-ray standards of the NRPA, the STUK, the SSM and the LNE-LNHB in the ISO 4037 narrow spectrum series in the range 40 kV to 300 kV (EURAMET.RI(I)-S3.2). Metrologia 2018, Volume 55, Technical Supplement.

Bjerke H, Plagnard J, Bordy JM, Kosunen A, Lindholm C, Persson L, Hetland PO. Comparison of the air-kerma standards of the NRPA, the STUK, the SSM and the LNE-LNHB in low-energy and mammography x-ray ranges (EURAMET.RI(I)-S14). Metrologia 2018, Volume 55, Technical Supplement.

Bjerke H, Plagnard J, Bordy JM, Kosunen A, Lindholm C, Persson L, Hetland PO. Comparison of the air-kerma standards of the NRPA, the STUK, the SSM and the LNE-LNHB in medium-energy x-rays (EURAMET.RI(I)-S15). Metrologia 2018, Volume 55, Technical Supplement.

Csete István, Toroi Paula, Steuer Andreas, Hourdakis Costas, Gabris Frantisek, Jozela Sibusiso, Kosunen Antti, Cardoso Joao, Sochor Vladimir, Persson Linda, GlaviČindro Denis, Arib Mehenna, Smekhov Mark. IAEA-SSDL bilateral comparisons for diagnostic level air kerma measurement standards. Physica Medica 2018; 47: 9–15. DOI: 10.1016/j.ejmp.2018.02.004

Huikari Jussi, Siiskonen Teemu, Kosunen Antti, Pousi Panu. Neutron field characteristics at radiation metrology laboratory of STUK. Radiation Protection Dosimetry 3.2.2018. DOI:10.1093/rpd/ncy007

Järvinen Hannu, Farah Jad, Siiskonen Teemu, Ciraj-Bjelac Olivera, Dabin Jérémie, Carinou Eleftheria, Domienik-Andrzejewska Joanna, Kluszczynskig Dariusz, Kneževič Željka, Kopec Renata, Majer Marija, Malchair Francoise, Negri Anna, Pankowski Piotr, Sarmento Sandra, Trianni Annalisa. Feasibility of setting up generic alert levels for maximum skin dose in fluoroscopically guided procedures. Physica Medica 2018; 46: 67-74. https://doi.org/10.1016/j.ejmp.2018.01.010

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Siiskonen T, Ciraj-Bjelac O, Dabin J, Diklic A, Domienik-Andrzejewska J, Farah J, Fernandez JM, Gallagher A, Hourdakis CJ, Jurkovic S, Jarvinen H, Jarvinen J, KnevežičŽ, Koukorava C, Maccia C, Majer M, Malchair F, Riccardi L, Rizk C, Sanchez R, Sandborg M, Sans Merce M, Segota D, Sierpowska J, Simantirakis G, Sukupova L, Thrapsanioti Z, Vano E. Establishing the European diagnostic reference levels for interventional cardiology. Physica Medica 2018; 54: 42-48. doi.org/10.1016/j.ejmp.2018.09.012

Tuovinen Hanna, Pelkonen Mila, Lempinen Janne, Pohjolainen Esa, Read David, Solatie Dina, Lehto Jukka. Behaviour of metals during bioheap leaching at the Talvivaara mine, Finland. Geosciences 2018; 8.
doi:10.3390/geosciences8020066

STUK's own serial publications

Holmgren O, Kojo K, Kurttio P. Radon concentrations in Finnish houses built in 2013-2015. Cores Symposium on Radiation in the Environment report. STUK-A261. Helsinki: Radiation and Nuclear Safety Authority; 2018: 110-116.

Järvinen Hannu (toim.). Säteilyn käytön turvallisuus kardiologiassa (Safe use of radiation in cardiology). STUK opastaa/Syyskuu 2018. Helsinki; Radiation and Nuclear Safety Authority: 2018.

Kallio A, Kämäräinen M, Turunen J. Radioactivity in the ashes from biomass-fired bioenergy production in Finland, 2016 case study. Cores Symposium on Radiation in the Environment report. STUK-A261. Helsinki: Radiation and Nuclear Safety Authority; 2018: 83-84.

Kurkivuori Janne. Gamma- ja röntgensäteilyttimien vertailu (Comparison of Cesium-137 and X-ray irradiations). STUK-TR 29/Lokakuu. Helsinki; Radiation and Nuclear Safety Authority: 2018.

Kämäräinen M, Kallio A, Turunen J. Energiantuotannossa syntyvän tuhkan radioaktiivisuus (Radioactivity of ash arising from energy production). Helsinki: Radiation and Nuclear Safety Authority. 19.4.2018.

Pastila Riikka (toim.). Säteilyn käyttö ja muu säteilylle altistava toiminta. Vuosiraportti 2017. (Radiation practices. Annual report 2017.) STUK-B 224. Helsinki; Radiation and Nuclear Safety Authority: 2018.

Pastila Riikka (ed.). Radiation practices. Annual report 2017. STUK-B 229. Helsinki; Radiation and Nuclear Safety Authority: 2018.

STUK brochures/Other publications

Jeminen S, Holmgren O, Kojo K. Radonpitoisuudet kuriin kattavilla radonmittauksilla ja nopealla korjauksella. Päiväkummun koulu, Vantaa. (Restricting radon concentrations in Päiväkumpu school using wide-ranging radon measurements and fast radon mitigation measures.) Ympäristö ja terveys -lehti 2018; 5: 68-71.

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STUK
Säteilyturvakeskus
Strålsäkerhetscentralen
Radiation and Nuclear Safety Authority

Laippatie 4, 00880 Helsinki
Tel. +358 9 759 881
Fax +358 9 759 88 500
www.stuk.fi